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METAL WORK

CONTAINING

Demonstration Lessons of all Tools and Principles ordinarily used in a Manual Training Centre, with full Scheme of Progressive Exercises approved by His Majesty's Inspector of Manual Training Schools, also Plan and Cost of Equipment of a Model Centre adapted to the Government requirements.

BY

J. S. MILLER

Organiser and Instructor of Metal Work to the Reading School Board

WITH ILLUSTRATIONS

WHITTAKER & CO.

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INTRODUCTION

BEFORE commencing the work planned out in the following pages, the boys will have had considerable practice in the use of the **rule, compasses** and **set squares,** to which should be added that of the **drawing board** and **T-square.**

They should also understand thoroughly the meaning of **plan** and **elevation,** and be able to draw the plan and elevation of simple models.

A working acquaintance with **scale drawing** is also necessary as a preliminary to the study of metal work.

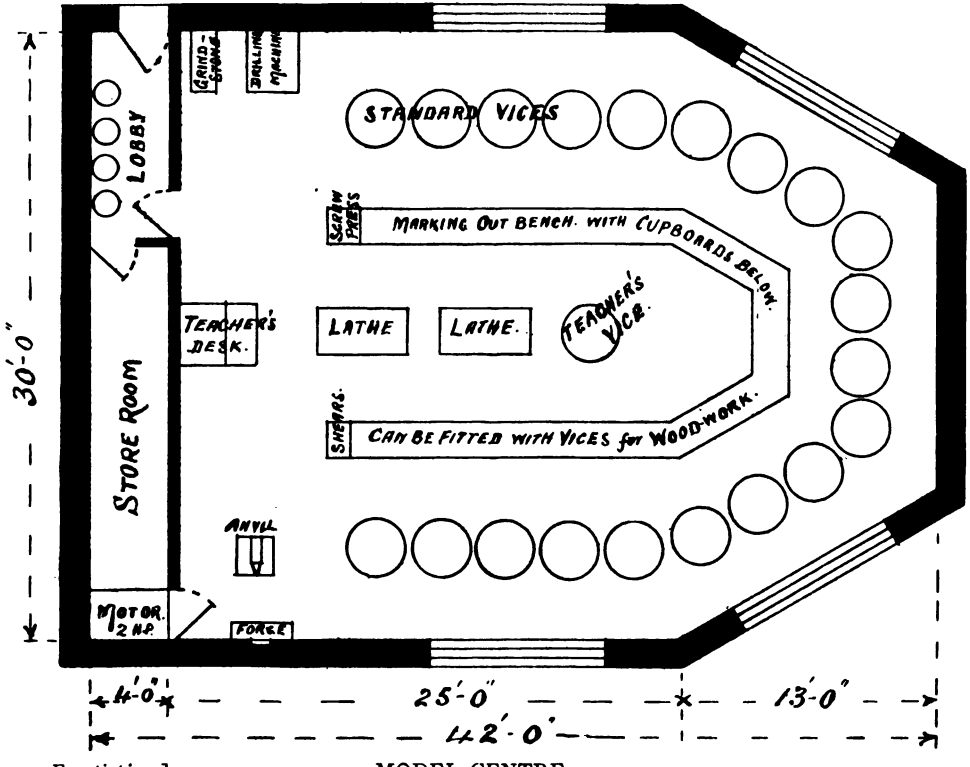
All drawing should be executed to as large a scale as possible.

As in most Manual Training Centres there is only one forge and one teacher, it is difficult to provide work at the forge for each boy. This difficulty is partially obviated by working certain exercises conjointly, namely, 11 and 12, 18 and 19, and 25 and 26. Similarly exercises 13 and 14 are worked conjointly, because, as a rule, only one set of stocks and dies is supplied.

Heavy chipping and surfacing are put late in the course, as this work is exhausting to most boys until their muscles have become hardened by practice in the use of the file.

The method of holding the various tools, and detailed instructions for marking out and drawing the exercises contained in this book, are fully illustrated by diagrams in the key to be published shortly.

READING, 1903. J. S. M.



Frontispiece.] MODEL CENTRE.

TEACHER'S HANDBOOK OF MANUAL TRAINING—METAL WORK

LESSON I

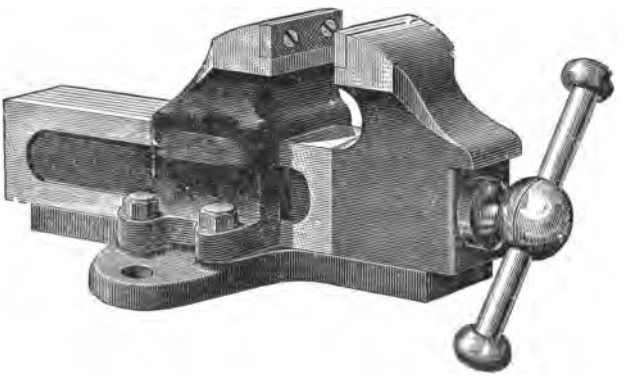
THE VICE

HOLD a piece of irregularly shaped metal before the class and tell them you are going to true, or make straight, one edge, using a flat file. Give a boy the piece of metal to hold, and tell him it must be held upright and rigid. Begin to file. Draw attention to the result; the metal moves either up or down with each stroke of the file. The boys will see that it cannot be held firmly enough with the hands. Can any boy suggest how the metal may be held quite rigid even when great pressure is put upon it? If none can tell, show them by putting a piece of metal in the vice and screwing tightly. Let several of the boys try to remove the metal without unscrewing the jaws—it is perfectly firm. Proceed to file, and draw attention to the difference. Elicit that a **vice** is therefore a **holding tool**. Ask for the name of any other holding tool (pincers, pliers, etc.). Withdraw the metal and proceed to explain the vice in detail.

The Jaws and Cheeks.—We will first of all talk about that part of the vice which actually holds the metal. Suppose a boy wanted to hold something firmly, but could not use his hands to do so, how could he manage it? If a boy wishes to undo a bad knot in a piece of string he makes use of his teeth; further elicit the term **jaws**. Tell the class that it is not the whole of the upper part of the vice which is termed the jaws, but only that portion which actually grips or bites the

metal. The outside, or curved portion, to which the jaws of a vice are fixed, is called the **cheek.**

Elicit that the hardest kind of metal must be used for the jaws. Take two lead clams, and place as a lining on each jaw. Screw tightly a piece of round steel between the jaws. Loosen and remove. Notice the result. The lead is indented. If that happens when the jaws have only been once used, lead the class to think of the condition of the jaws after a year's use; and so emphasise the need of using a hard metal. Repeat the operation with the lead removed and note the difference.



PARALLEL VICE.

Let the boys examine the vice, and see that the jaws and cheeks are not made of the same material. Hardened steel is too expensive to be used in large quantities, and it is not necessary for the cheeks to be as hard as the jaws, therefore the former are made of wrought or malleable iron. Let the boys also explain how the jaws are fastened to the cheeks. They are either screwed, welded or riveted. Now let the class examine the inside of the jaws, and educe the reason for the small furrows or teeth with which the jaws are lined — the firmer grip which is thus procured.

Illustrate the movement of the jaws.

The Handle or Lever.—Give the boy a piece of metal, and tell him to fix it in the vice ready for filing. (This has several times been

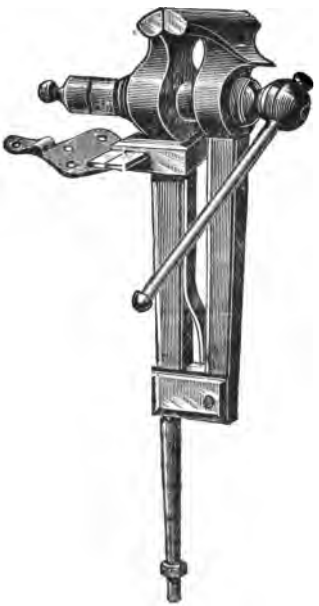
done by the teacher during the lesson, so the boys should find no difficulty). Elicit how it was done—by turning the handle. Let the boys examine the handle, and elicit that it is a loose rod of metal passed through a hole in the head of the screw, and having a knob at each end to prevent it slipping out. Turn the handle slowly, and ask the boys for any simultaneous movement which they notice—the turning of the screw. Turn the handle slowly back again, and ask them to mention any other movement which they may notice—the closing of the jaws. Thus there are three movements taking place at the same time, viz., the handle is being worked, the screw is being turned, and the jaws are either opening or closing. Ask the class why the handle is made loose, so as to slide up and down, instead of being fixed.

Explain the two reasons—(1) Place a piece of metal in the vice and close the jaws so that the handle shall be left projecting above the vice. Show the difficulty of filing with the handle in this position; it is therefore allowed to drop below without disturbing the screw. (Warn the boys against catching their fingers between the knob and the screw head when dropping the handle). (2) Explain that when tightening a piece of metal, after the handle has been drawn round as far as possible in an upward direction it can be pushed up, or through, and a firmer grip or greater leverage obtained by pulling and pressing in a downward direction.

The Screw and Spring.—Remove the spring from another vice, and leave the jaws apart. Open the jaws of the vice which is being demonstrated. Allow two boys to close the jaws of each vice respectively. Now tell each to open the jaws by turning the handle or lever. The boy at the first vice opens his without difficulty; but though the second boy turns the lever, and the screw works, yet the jaws remain closed. Instruct the boy to pull them apart. Let the vice be examined, and elicit the fact that the spring has been removed. Replace the spring, and let the class note the result. Thus it is the action of the screw, combined with that of the spring, which causes the movement of the jaw.

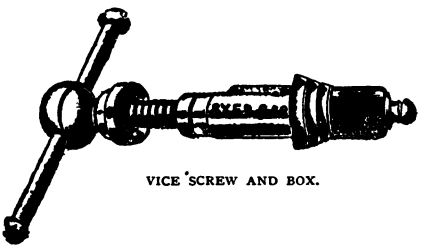
Let the class now note, by experiment, that one jaw only moves (the other being stationary).

If a **staple vice** is at hand let the class examine it carefully and note the action of the jaws. Show that the arms or legs are worked upon a hinge, and that when the jaws are closed they are parallel; but as the movable arm is opened, the jaw moves outward, describing a slight downward curve, so causing the metal to be gripped by the lower portion of the jaws only.



STAPLE VICE.

Compare this action with that of a parallel vice, and elicit that in the latter the jaws move in a straight line, or



VICE SCREW AND BOX.

parallel to one another; thus we get the term **parallel vice.**

Kinds of Vices most Commonly Used.

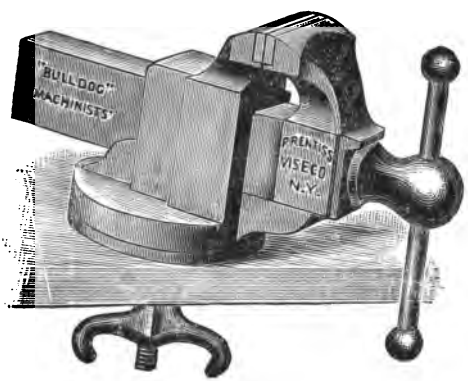
Parallel Vice (already described)—bolted to the bench.

Staple Vice.—Secured to the bench by means of a wrought iron strap and plate. The plate is screwed or bolted to the bench at one end, and has an elongated hole at the other. The wrought iron strap, with a corresponding hole, holds the spring and vice to the plate by means of a **gib** and **taper cotter**. The gib prevents the strap from opening.

Standard or Portable Vices.—Very convenient to move from one part of the shop to another.

STANDARD VICE.

TABLE VICE.



ROTARY VICE.

HAND VICE.

Table Vice.—Fixed to the table by means of a thumbscrew; very handy where a bench is not accessible.

Swivel or Rotary Vice.—Fixed upon a circular seating, upon which it revolves, thus enabling the work to be operated upon from any position in which the workman may be standing without removing it from the vice.

Hand Vice.—Held in the hand—for small work which does not require a very firm grip.

When the vice is to be used for soft metal, such as brass, **lead clams** should be employed to prevent the teeth of the jaws injuring the surface of the metal fixed between them.

LESSON II

THE FILE AND FILING

SHOW the class a piece of metal, with one edge irregularly cut. Draw attention to this irregular edge, and say that it is to be made straight. Place the metal in the vice and proceed to file the edge true. Let the class notice the difference, before and after filing, and say to what it is attributed.

Each boy should now take his flat file and examine it: it is made of hardest tool steel, to scratch the metal upon which it is used. Ask the class which part of the file really does the work. How are the **teeth** formed? Draw from the boys as far as possible, but where necessary explain, that the teeth are cut into the steel before it is hardened, a broad chisel and heavy hammer being used. Most files in ordinary use are **double cut**; that is, grooves are first cut with a chisel diagonally across the surface of the file (single cut—used upon brass and the softer metals); a second or up-cut is then made, the diagonals running in the opposite direction, making diamond-shaped points or teeth (cross cut).

The teeth vary in size and number, from 50 to 70 per inch. When one side of the file is cut it is laid upon a piece of lead, to prevent the teeth becoming flattened while the other side is being cut. This is done in exactly the same manner as with the former side.

The file is now dipped into a mixture of yeast and the grounds of malt liquor, or some other equally sticky substance, and afterwards rubbed with common salt mixed with cows' hoofs. This preserves the teeth from the direct action of the fire during the process of hardening, preventing them from becoming white hot before the body of the file

becomes red hot. When the file becomes cherry or blood-red, it should be plunged into cold water, and afterwards into oil. This heat is often indicated by the burning of the salt mixture. If the file becomes bent while the teeth are being cut it must be straightened while red hot with a lead hammer. Explain that lead is used so that the teeth may sink into it when the blow is struck, and not become bent or blunt by striking a hard unyielding surface.

Tell the class that the pointed end is called the **tang.** This is driven into a wooden handle, generally of beech or ash, as being very uniform in texture and hardness. The handle has a strong brass or iron ferrule binding the end into which the tang is driven, to prevent the wood splitting. Before leaving the filemaker's hands, the tang is softened to render it less brittle, and therefore less liable to break while imbedded in the wood.

Explain that the **heel** or **shoulder** prevents the tang from forcing its way through the handle, and so into the hand. It is advisable to have a handle for each file in use, as otherwise the constant changing wears and splits the wood, and the tang will not hold firmly.

When each part of the file has been fully dealt with proceed to explain the **method of filing.** Place a boy before the vice in the correct position for filing, and draw from the class that the feet must be placed firmly upon the ground, and from 12 to 18 inches apart, with the foot nearer the vice slightly in advance. The knees should not be rigid, but allowed to bend with the forward movement of the body. When working, the elbow should be about level with the top of the vice. In the case of a very short boy, a small platform should be provided to elevate him to the required height.

Now explain how the file should be held. Hold the handle firmly in the centre of the palm of the right hand, with the thumb and index finger pointing along the handle, and the remaining fingers grasping it on the under side. Place the thick part of the thumb of the left hand near the end of the file, and bend the fingers downward, to grasp the file on the under side. When a very small file is used it should be held in the same manner with the right hand, but the thumb and first finger of the left hand will be sufficient. Further explain why

this method of holding should be adopted. Show the class that, if the file is grasped in the same manner as a hammer, the hand is very liable to slip along the handle. The right arm should not be held pinned down to the side, but allowed to move freely from the shoulder with the natural movement of the body.

Let a boy secure a piece of metal in the vice, ready for filing, and show, by experiment, that the metal must not project too far above the jaws, or an unpleasant, screeching noise will be made when filing, due to the vibration of the metal.

The file should be used with **long, steady strokes,** reaching with a continuous, even pressure from end to end, and not with short strokes with the middle of the file, or the teeth in that part will become worn, thus rendering the file useless. If the boys examine their files they will notice that all the teeth slope towards the "**point**" of the file; therefore, the pressure should be put on the **forward stroke only.** In returning, the file should either be allowed to slide over the metal, or should be lifted off. Any pressure upon the file in the backward stroke will only break the teeth. During the whole of the stroke the file must be kept perfectly horizontal. There is often a tendency to slightly dip or raise the "point," or describe a curve with the file instead of a straight line. The boys will see the result of this: the edge of the metal becomes either rounded or bevelled. Warn the class against rubbing their fingers over the file or work, as this causes the file to slip over the surface and prevents it biting.

When cast iron is to be filed, an old file should be used until all the hard skin has been removed, as this spoils a good file. A better method is to chip the surface of the cast iron all over before using a file.

Tell the class that the harder the metal the finer must be the file. Cast iron, copper and brass require a sharper file than steel or wrought iron. A file which is too much worn for filing brass makes a good file for wrought iron, and even after it is useless for wrought iron it can still be used for steel.

When a broad surface is to be filed flat, the file should not be used continually in the same direction, but should cut from side to side,

and from end to end, and diagonally; thus any unevenness left in one direction will be taken off in another. Filing from corner to corner is particularly advisable. Use the whole length of the file, and allow it to travel over the entire surface. Filing in patches is a great mistake.

When the work is finished, the file should be laid flat upon the metal, and parallel with the body. Hold it with both hands—one at each end—and draw it over the metal, pressure being used only on the stroke away from the body. Use short strokes. This is called **draw filing,** and is done to remove the marks left by the file when employed in the usual manner.

Show the class that files vary in size and number of teeth, and are known as **rough, bastard, second cut, smooth,** and **dead-smooth.**

The **rough file** has large but comparatively few teeth.

In the **bastard** and **second cut** the teeth are smaller but greater in number, while those of the **smooth** and **dead-smooth** are still finer.

Let the class name the ordinary types of files according to their shape:—

Flat Files.—Used chiefly for filing flat surfaces and when a large quantity of metal is to be removed. Some flat files are made with a plain edge, this being known as a **safe edge.** When a surface which is at right angles to another is to be filed, the safe edge prevents the side of the metal against which the file is placed from being damaged.

FLAT FILE.

HALF ROUND FILE.

Half-round Files.—Used for filing inside holes, curves and hollows. When using a half-round file, do not file straight backwards and forwards, but turn the wrist from left to right, and *vice versa*, so giving a forward screwing motion.

Round Files.—Generally employed for enlarging holes and slots, and used in the same way as half-round.

Triangular Files.—Useful for getting into the corners of square holes, slots, etc.

Square Files.—Used for filing out square holes.

The round, square, and triangular files are usually drawn to a point, and are then called "**taper round,**" "**taper square,**" etc. When they are left the same thickness from end to end they are spoken of as "**parallel round**" or "**parallel square**" as the case may be.

Draw from the boys that, after the files have been in use some time, the teeth become clogged, and the files are thus rendered useless. Tell them the best method of cleaning the files. If the teeth are clogged with grease or dirt they should be soaked in hot, strong, soda water, and the grease afterwards brushed out; but if the teeth have become clogged with metal dust, the only way of cleaning is by scraping along each groove with a pointed piece of steel.

LESSON III

THE SCRIBER AND SCRIBING

TELL the class that the exercise which they have just drawn on paper has now to be drawn on the metal. Ask the boys what they consider the best method of doing this. They will probably answer "with pencil or chalk." Show, by experiment, that pencil or chalk lines could not be made fine enough, as these substances are too soft, and would wear away very rapidly, and the lines would be obliterated. Educe that some hard substance must therefore be used, which will scratch the metal.

The tool employed to effect this is called a **scriber** (comment briefly on the word Scriber—Lat. *scribo*, to write). Allow the class to examine the tool, and so draw from them that a scriber is a thin rod of hard steel, with one end drawn or ground to a rather long, fine point, which is used for **scribing** or drawing lines upon metal. Tell the class that the point must be harder than the metal which it scratches, though it should not be too hard or brittle or it will break off. It should be tempered to a brownish yellow. The method of hardening is described in the Lesson on "Hardening and Tempering." Mention may also be made of the thickness of the metal used, which is generally from $\frac{3}{32}$-inch to $\frac{1}{8}$-inch diameter.

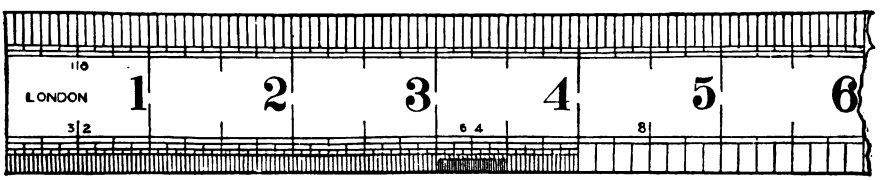
The scriber is held between the thumb and second finger, with the first finger resting lightly upon it—in the same way as a pencil is held when drawing.

LESSON IV

STRAIGHT-EDGE

PREPARE a piece of metal having one edge irregularly filed, showing hollows and lumps, another edge almost correctly filed, so that the flaws can only be detected by careful examination with the aid of a straight-edge, and a third edge filed perfectly straight.

Tell the boys that in many of their exercises they will be required to true, or make straight, one edge of the metal before they can begin to mark out. How is this tested? They will probably say by closing one eye and bringing the work on a level with the other, and looking



STRAIGHT-EDGE.

along the edge. Tell them that this method is sometimes adopted but is not sufficiently reliable, and that it requires a very clever and experienced workman to test in this manner. They may also say that we might use another edge which we know to be true or straight. This is the safer method. Can any boy suggest a name for such an instrument? **Straight-edge.**

Show the piece of prepared metal, and tell a boy to find out with the aid of a straight-edge whether a certain edge is true. He will very probably hold up the piece of metal, and lay the broad and flat face of

the straight-edge upon it. Tell the class that this is not a correct method, as it is the **edges** of the straight-edge which have been made true and not the flat surfaces, and proceed to show how an edge should be tested.

Hold the unevenly filed edge before the class; they will readily see that it is not true, but test it by placing the edge of the straight-edge upon the edge of the metal, and holding both between the eyes and the light. Draw from the boys that the light can be seen at many points between the metal and straight-edge. Now show the edge of metal which is almost true. Allow one or two boys to test this with the eye. They will probably be able to find no fault in it. Carefully place the straight-edge upon it, and hold to the light; the boys will be able to see faint streaks of light. Impress upon the class the need of actual testing even when the metal may appear straight, and the risk of relying upon the eye. Lastly, test the edge which is true, and emphasise the fact that, if the metal has been cut or filed perfectly straight or true, the line where the metal and straight-edge meet is hardly discernible, and no light can be seen through.

Ask for the name of the material of which the straight-edge is made, and why wood is not used. Show that the constant testing of hard surfaces would quickly wear away and damage the soft wooden surface; and that even ordinary steel has to be carefully hardened in order that the edges may keep as true as possible; but it must not be too hard or it becomes brittle.

Draw from the boys that a straight-edge is also used for taking measurements and testing dimensions; thus it is also a standard rule.

Before the boys begin to use the rule for measurements, care should be taken that they thoroughly understand all the divisions marked upon it, and can distinguish between $\frac{1}{16}$, $\frac{1}{32}$, etc.

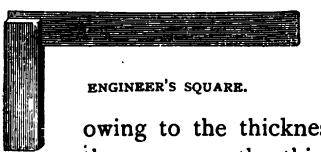
The accuracy of the straight-edge is tested in the same manner as that of the surface plate (*see* Lesson on the "Surface Plate").

LESSON V

THE ENGINEER'S SQUARE

SHOW the class a piece of metal cut at right angles, and ask them how to find out whether the corner is square. Let them examine an engineer's square, and notice that it is made of steel, and is composed of two parts, viz., the **stock** and the **blade.** The blade is often made of tool steel. Elicit that as the square has to be continually used upon metal it must be made of a hard substance, to prevent it becoming worn or broken, as would be the case if made of wood.

Let the boys notice the difference in the thickness of the blade and the stock; the latter is often four or five times as thick as the former.



ENGINEER'S SQUARE.

Explain and illustrate the reason for this: by testing a piece of metal with the stock of the square show how much more difficult it is to see any small fault, owing to the thickness of the metal and the shadow which is thrown upon the thin edge by the thicker metal placed above it. Test an edge with the blade of the square, and show how much more accurately this can be done, as the fineness of the edge allows the light to penetrate more easily, and thus enables flaws to be readily detected. Show the class that in consequence of the stock being much thicker than the blade, the square is more rigid, and can stand upright when being used for testing surfaces at right angles. Show, by experiment, that the thickness of the stock also enables the blade to be placed flat upon a surface, at right angles to the edge against which the stock is placed, while a line is scribed. Show that if the stock and the blade were of the same thickness, the stock would be very liable to slip over

the surface, and thus make scribing very difficult. The extra thickness allows the metal to be brought close up to the edge, and keeps it firmly in place. Show also that, when testing, the square should be held firmly by the stock between the thumb and three fingers.

Explain the **various methods of making an engineer's square.**

In some cases a piece of metal is filed to a certain thickness to form the stock. A saw cut is made in one end of this, so that the blade may be inserted in the saw cut at right angles to the stock. Holes are then drilled through the double thickness, and the two are first secured with two or three rivets, and then brazed together.

A better method than this is to cut the form of the square out of sheet steel, and then thicken the stock by riveting another piece of steel on each side.

A better method still is to forge and file the square out of a solid piece of steel. Care should be taken to see that the blade is not winding.

Now show the class how to test the accuracy of the square. Place the edge of the stock against the true edge of the surface plate, with the blade resting upon the plate. Scribe a line along the inner edge of the blade; turn the square over, and from the same edge draw a line close to the one already drawn. If the lines are parallel, the square forms a true right angle—90°.

Elicit that the square is used for testing and scribing lines at right angles.

LESSON VI

THE SHEARS AND SHEARING

TAKE a sheet of metal, and tell the class it is to be cut into a number of smaller pieces. If, instead of metal, paper had to be cut, how would you do it? Explain that the tool or machine used for cutting metal is very similar to a pair of scissors, and is called a **shearing machine** or **shears**.

Let the class now examine the shears. Elicit that they consist of two blades—top and bottom. The bottom blade is screwed to the body of the shears. The upper blade is screwed to a movable arm which is bolted to the body of the shears. This bolt forms a hinge upon which the arm works. The top blade is worked by means of a lever.

SHEARS.

Place a piece of metal in the shears and cut off a narrow strip. The class will notice that the waste piece falls to the right or **back**, as it is called, of the shears. Elicit that in order to cut metal the blades must be made of hardened tool steel. Let the class notice the cutting edge; they will readily see that it is not the keen edge of a knife, which would easily chip with the hard metal, but that it is ground to a stout angle, generally 87°; this strengthens the edge without lessening its cutting power.

The blades are screwed to the arms in order that they may be easily removed for grinding. When the sides of the blades begin to wear from the continual friction, narrow strips of metal, called **liners**, are inserted behind them. These take up the wear, and keep the blades in touch. Never allow the blades to become blunt, or the metal will tend to bend and wedge itself.

For easy cutting the metal should be cut with the portion of the blades nearest the joint.

A **stop** is sometimes arranged to prevent the metal from lifting while being cut.

The body of the shears is generally made of cast iron, the lever and connections of wrought iron or mild steel, and the blades of tool steel, hardened and tempered to a purple or reddish-brown.

Shears are sometimes driven by "power." *N.B.*—Cast iron and hardened steel are too brittle to be cut with the shears.

TINMAN'S SNIPS.

Explain to the class that when sheet tin has to be cut into various shapes, a tool resembling scissors, called **tinman's snips**, is used. They consist of two pieces of tool steel riveted together so as to form a double lever, one end forming the blades and the other the handles. The blades are hardened, tempered and ground as for shear blades.

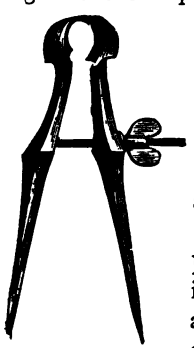
LESSON VII

WING COMPASSES AND SPRING DIVIDERS

Wing Compasses.—Elicit from the class that wing compasses are used for drawing circles in the same way as ordinary compasses, a steel point taking the place of the pencil. They are also often used in the place of dividers. Draw from the boys that wing compasses are made of tool steel, and that the points must be hardened and tempered to prevent them becoming bent or blunt.

WING COMPASSES.

Ask the class why the term "**wing**" is given. Illustrate the use of the wing, by showing that it is used to guide the leg into the required position, and to secure it in place by means of a thumb screw. Let the boys examine a pair of wing compasses, and notice that the legs are held together by means of a rivet, which forms the joint. Show the class how necessary it is that the joint should work smoothly and without jerking, so that no time need be wasted in setting them accurately or in taking dimensions.



SPRING DIVIDERS.

Explain **the manner in which wing compasses are tested.** One leg of the compass is held in each hand; with the hands near the chest and arms pressed tightly against the body, draw the legs of the compass steadily apart. Any jerkiness or unevenness of the joint can then be distinctly felt.

Spring Dividers.—Draw from the class that spring dividers are

made of tool steel, hardened and tempered, and that they are used for accurately taking fine measurements.

Explain **the construction of spring dividers.** The legs are made in one piece, flattened at the centre to form a spring, which tends to keep them apart. This spring takes the place of a joint.

Point out that the dividers are adjusted by means of a screw and wing nut. The screw is riveted to one leg and passes through an oval hole in the other.

The legs are closed by means of the nut working upon the screw and so compressing the spring, which, when released, allows the legs to fly open.

LESSON VIII

THE CENTRE PUNCH

TAKE a pair of wing compasses and proceed to draw a circle upon a piece of metal. The class will notice that this cannot easily be done on account of the point of the compass slipping. Ask how this may be overcome. Show that the point of the compass must not be driven into the metal, or it will bend and become blunt; a centre must therefore be made to receive the point of the compass and prevent it slipping upon the surface of the metal. This is done by means of a **centre punch.**

Allow the class to examine the centre punch, and draw from them that it is a piece of hard steel, and octagonal in shape to give a firmer grip. One end is ground in the form of a short cone. Show that the point must be harder than the metal which it strikes, to prevent the point being damaged, though it should not be too hard or brittle or it will break off. It should be tempered to a brown-yellow.

CENTRE PUNCH.

The method of hardening is described in the Lesson on "Hardening and Tempering." When used, the centre punch should be held vertically between the tips of the fingers and the thumb. The centre punch is also used to make a centre for drilling a hole.

LESSON IX

THE HAMMER

ASK the class the name of any striking tool—hammer, mallet, chopper, etc. Elicit that the tool most generally used for striking is the hammer; that this is composed of two parts—the **head** and the **shaft**; and that as the head is often used for striking hard metals and heavy blows, it must be made of hardened steel.

Explain that the ends only of the head are hardened, the centre being left soft. This is done so that the ends may not become indented or burred.

They must not be made too hard, or they will become brittle, and pieces will be liable to chip off the edges.

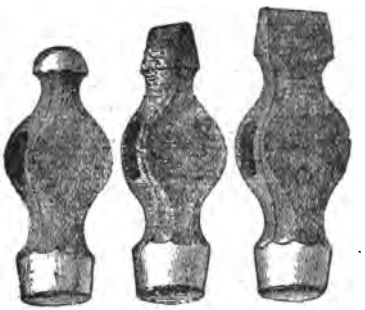
The centre of the head is left soft to render it less brittle, as the head is more likely to fracture here than in any other part.

Explain that the hole in the centre of the head, through which the shaft passes, is called the **eye**, and is oval in shape. It is larger at each end than in the middle, so that the thick part of the shaft at one end, and the wedge driven into the other, hold the shaft firmly in place, and prevent the head slipping off.

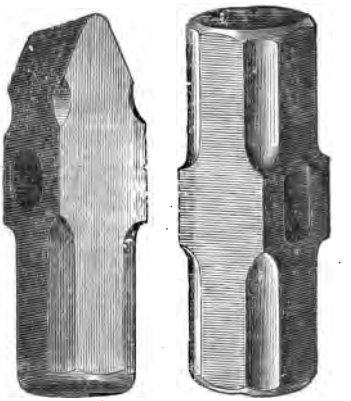
One end of the hammer head is always round, flat, and smooth, and is called **the face.** The opposite end is called the **pane** or **peen,** and varies in shape and size according to the work to be performed. The pane of the engineer's hammer is ball shaped, as it is frequenlly required for spreading metal, as in burring, hammering down rivets, joining a scarf in welding, etc. The pane of the carpenter's hammer is flat and tapered so that it can be used to tap a nail held between the finger and thumb before driving it home.

The sledge hammer and plumber's hammer are straight paned; that is, the panes lie in line with the shaft, and are used for fullering.

The face end of a hammer is always made heavier than the pane end, so that the hammer will naturally fall into its proper position for striking when taken into the hand. Being heavier at the end which points to the ground, the force of gravity will assist in striking the blow. Always bring the face of the hammer down squarely upon



HAMMER HEADS.



SLEDGE HAMMER HEADS.

the work to avoid dents being made by the edge of the face striking the metal.

Let the boys now describe the shaft. It is made of a slightly flexible wood, usually ash, so that it will give to the blow. Hard woods, such as oak, should never be used, as they are too brittle, and will not withstand the shocks to which the shaft is subjected when a blow is struck. Again, the shaft should not be too flexible, or the hammer is likely to rebound and strike the face of the operator.

One end of the shaft is pared down just sufficiently to allow it to pass through the middle of the eye, and a saw cut, about three-quarters of an inch long, is made to start the wood or iron wedge which is driven down through the eye to spread the wood, and so wedge it firmly into the head.

In hot weather, the hammer head is liable to become loose. This is due to the heat drying the wood, and therefore causing it to shrink. To remedy this, put the hammer into water; this will cause the wood to swell.

Smiths' hammers should often be treated in this way, as the heat from the hot metal shrinks the shaft very quickly.

The length required for the shaft depends on the weight of the hammer head. For a small hammer one foot will be long enough, and for a sledge hammer two feet nine inches.

HAMMER SHAFT.

Now explain **how the hammer should be held.** Let a boy strike one blow, holding the hammer just below the head, and another, holding the hammer in the correct position. Let him describe the difference. Show the class that the hammer should be grasped firmly in the right hand, leaving about an inch of the shaft projecting below.

When striking very light blows the hammer should be used from the wrist, in heavier blows from the elbow, and in very heavy blows from the shoulder. The sledge hammer should be grasped with both hands, and swung in a circle.

When striking, the hammer should point directly from the shoulder, *i.e.*, should descend in a vertical plane, unless such a movement is impracticable. When used in any other direction the force of gravity does not help, but hinders. This can be more fully explained by holding a heavy hammer horizontally, and striking a blow upon an object placed in front of the body. It will be found much more difficult, and greater energy will be needed. There will also be a greater strain upon the wrist.

Refer to the difficulty a workman finds when chipping a ceiling, or hammering something above his head. Show that gravity tends to pull the hammer to the ground. When possible, it is always better for the operator to be above his work.

LESSON X

THE CHISEL AND CHIPPING

TAKE a piece of cast iron and comment upon the hard coating or skin, which is formed by the hot metal melting the sand while casting. If this were removed by filing it would spoil the file and render it useless. Explain that it must be **chipped** over, using a hammer and **chisel.**

Let the boys examine their chisels, and elicit that they are made of hard steel and are octagonal in shape to give a firmer grip. One end of the chisel is slightly drawn down, to form the **head,** which receives the blows. This prevents it being burred over. The other end, which forms the **cutting edge,** is drawn down about $2\frac{1}{2}$ inches to the required shape, and is afterwards hardened, tempered and ground.

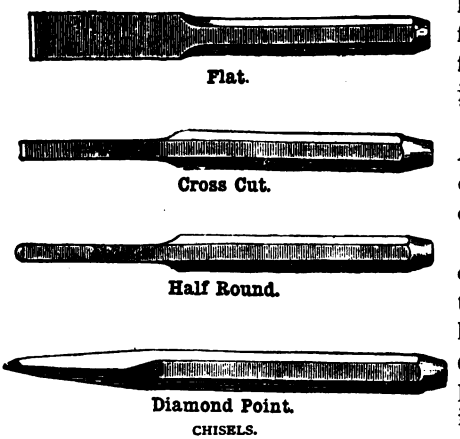
Explain that chisels vary in size and shape according to the purpose for which they are to be used. Those in most general use are the **flat** and **cross-cut chisels.** We will first of all talk about the **flat chisel.** As its name implies, the flat chisel has a broad, flat cutting edge, and is used for chipping flat surfaces or cutting sheet metal. It is drawn down on both sides for about $2\frac{1}{2}$ inches in the form of a wedge, and is broader at the cutting edge than in the body. Elicit from the class that if the chisel were ground to a knife or razor edge it would not penetrate into the metal but pieces would break off. Show that, in order to make the end sharp but rigid, two facets are ground, forming an angle of from 80° to 90°.

Now proceed to describe the **cross-cut chisel.** As its name indicates, the cross-cut chisel is used for cutting across the metal, and for deep grooves, such as key ways, etc. The cutting edge varies in width according to the size of the grooves to be cut. The chisel tapers

from the cutting edge towards the body; thus a clearance is allowed, which prevents the tool becoming wedged in the groove. The cutting edge is ground to the same angle as for a flat chisel.

Other forms of chisels are—

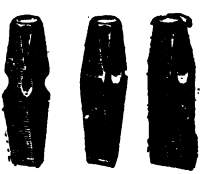
Round-nosed.—Named after the shape of the point, and used for drawing over a hole, when the hole is running out of centre while drilling (*see* "Drilling"). This form of chisel is also used for making grooves in bearings to receive oil.



CHISELS.

Diamond - pointed.—Also named from the shape of the end, and used for chipping into sharp corners.

Explain that these chisels are all used for cutting **cold metal**. When hot metal is to be cut a **hot chisel** or **hot set** is employed. The latter name is given to the tool on account of the cutting edge being ground and tempered to suit the cutting off of hot metal, which being softer than cold the facets are ground to a more acute angle.


HOT AND COLD SETS.

Now show the class the **correct method of holding the chisel for chipping.** Grasp the chisel firmly, but not too tightly, in the palm of the left hand, with the fingers and thumb doubled around it as near the head as possible. If held near the cutting edge, the hand will cover the part of the material being cut; and the tool cannot be held so steadily as when grasped near the head. The chisel should be held

in a direction slanting to the work and not in an upright position. If held upright, or nearly so, the chisel will cut too deeply and gash the work, and if it has too great a slope it will slip over the surface. If the chisel cuts too deeply lower the head, and if not deep enough raise the head.

When chipping cast iron the surface should be chipped from the edges to the centre, as the metal, being brittle, would otherwise break when the chisel neared the edges, for there would not be sufficient metal to withstand the blows.

When, however, the chisel is used for cutting a bar it must be held upright. When using a sledge hammer to strike a chisel, as in the cutting of heavy bars, the chisel is held by means of a handle or rod to prevent the hand being injured. The bar is held in one hand, and the **rod chisel** in the other, while a second person strikes the blow. Chisels or sets used for cutting hot metal should always have a wooden handle attached, to prevent the heat being carried to the hand.

LESSON XI

THE SCRIBING BLOCK OR SURFACE GAUGE

SHOW the class a piece of sheet metal with one straight edge, and tell them that two straight lines are to be drawn parallel to that edge. Ask how this may be done. The best method is by using a **scribing block.** Let the class examine the scribing block: it consists of a turned wrought iron or steel pillar fixed to a cast iron base, the bottom of which is made perfectly true. A scriber (*see* Lesson on "Scriber") pointed at both ends, one of which is bent at right angles, is passed through a hole in a small bolt which secures a brass slide or clip firmly to the pillar, and which, when screwed tightly by means of a wing or milled nut, holds the scriber in position. Show that the slide can be moved either up or down the pillar, carrying the scriber with it.

SCRIBING BLOCK.

Place the block upon a true surface called a **surface plate,** and show that wherever it is placed the point of the scriber remains at the same height. Place the piece of metal at right angles to the surface plate with the true edge resting upon it. Adjust the scriber to the required height. Bring the point of the scriber to the metal, and slide the block along the plate by placing the hand firmly on the base, allowing the pillar to come between the first and second fingers.

The scriber should not be drawn along the metal at right angles, or the point will probably break off. It should be sloped at such an angle that the point may be **behind** the pillar, and not **before** it. This can

be illustrated by drawing a line upon a piece of new tin. The class will notice that when the scriber is used at right angles, the metal collects in front of the point and impedes its progress, causing it to jar, and if hard metal is being used, to break off.

By testing various parts of a line with the scribing block let the boys see that the line drawn is parallel to the surface plate. Draw attention to the edge of the metal resting upon the plate. This being true the line will be parallel to the edge as well as to the plate. Move the metal to another part of the plate, still keeping it at right angles. Test the line with the scribing block without altering the scriber; show that the line is still parallel, proving that the edge of the metal is true.

Now take a piece of metal with an irregular edge. Place in position on the plate, and draw a line with the scribing block as before; the boys will notice that the line is parallel to the surface plate but not to the edge of the metal. Remove to another part of the plate, and draw a line; it will probably cross the one already drawn, proving that when the piece of metal has to be replaced on the surface plate for other lines to be drawn parallel to that already drawn, it is necessary that the metal should have a true edge.

When scribing lines, the point of the scriber must not project too far from the pillar, as this will cause it to spring while scribing, giving an irregular line.

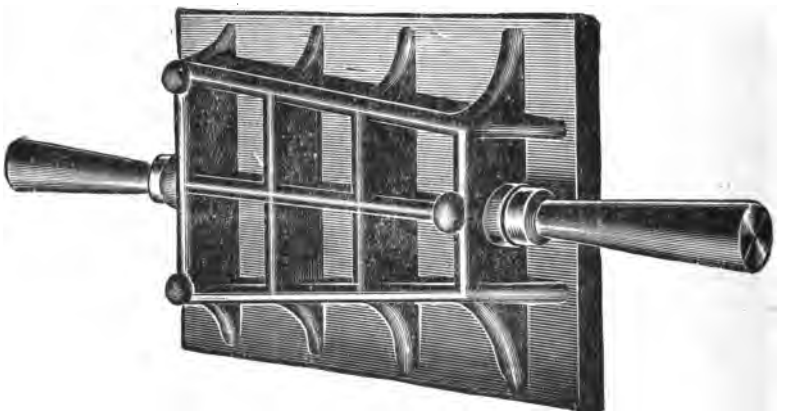
Explain that the scribing block is also used as a **surface gauge**; the bent end of the scriber is adjusted to the required height, and passed over the surfaces or points to be tested.

The surface plate and the base of the scribing block should be kept free from dirt and grease.

LESSON XII

THE SURFACE PLATE

EXPLAIN that when surfaces which are broader than the straight-edge are to be tested it is necessary to use a **surface plate**. Let the class examine a surface plate, and elicit that it is simply a plate of cast iron,



SURFACE PLATE.

the upper surface and edges of which have been made as true as possible by planing, filing and scraping.

Turn the surface plate over; the boys will notice that it is strengthened on the under side by ribs, which also form feet. To enable the plate to be easily moved, handles are screwed to the ends. When the plate is to be used for testing, the surface is smeared thinly

with a mixture of red lead and oil. The work is laid upon the plate and gently rubbed; the high parts will be reddened. These must be either filed down or scraped, and the work tested again until the whole of the surface becomes equally reddened.

The **scraper** is generally made from an old file, ground to shape, and kept well sharpened. The sides of the surface plate are generally trued to allow try squares, etc., to be tested.

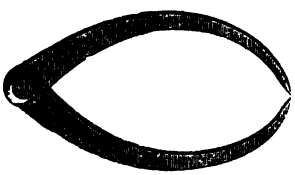
In making a standard surface plate, three plates must be made as true as possible, and compared with one another, No. 1 with No. 2 (No. 2 being eased to fit No. 1), then No. 2 with No. 3 and so on, until all the surfaces are perfectly flat.

LESSON XIII

CALLIPERS

SHOW the class a piece of round metal thicker in the centre than at the ends. Tell them you want to know the thickness of the middle portion. Give a boy a rule, and tell him to measure the thickness. The boys will at once see that this cannot be done. Elicit that a particular tool must therefore be used—**gauge**.

Show the class a fixed gauge to fit the centre. With the same gauge proceed to take the thickness of the ends. Show that this cannot be done, as the gauge is not movable; we must therefore use another gauge. A movable gauge, however, will suffice for both measurements.



OUTSIDE CALLIPERS.

Take a pair of outside callipers, and test both thicknesses; also test the sizes of other pieces of metal. Give the boys the name **callipers**, and elicit that they are a form of movable gauge. These are called **outside callipers**, and are used for outside measurements. When the measurement has been taken, find the distance between the points of the callipers by placing on a rule. Draw attention to the shape of outside callipers, and show the class that the legs are bowed in order to let the thickness of the metal come between them in taking diameters of bars, tubes, etc.

Now show the boys a hollow bar or tube of metal, and tell them you want to find the inside diameter. Show that this cannot be done with

outside callipers. Tell them that there is a special kind of callipers used for testing the inside diameters of holes, tubes, etc.

Let the class examine a pair of **inside callipers**, and compare them with outside callipers. The legs are straight and tapered, with the points turned outwards. When the legs are closed, the distance between the points gives the smallest measurement which can be taken with that particular pair of callipers. Explain that the larger the work to be tested the longer must be the legs to give the distance required. **The callipers should be held near the joint**, and should not be sprung into the space to be tested. The points should just touch the surfaces.

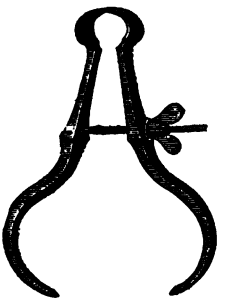
Explain the construction of inside and outside callipers. The legs are made in separate pieces, and are secured by a rivet, with a washer on each side, forming a joint. **A good joint is one of the most important points in a pair of good callipers.**

ODD LEG CALLIPERS.

To test callipers, place the arms close against the body, with the hands before the chest. Take one leg in each hand, and draw them steadily apart. If any jerking is found the callipers have a bad joint. This will cause a great deal of trouble and loss of time in adjusting. A good joint should work smoothly and without any jerking. Good callipers are particularly necessary when any turning is to be done, as they are then continually in use. Warn the class against carelessly opening and closing their callipers. Never open the callipers to a much greater width than is necessary. For instance, when a dimension of about 3 inches is to be taken, do not open the callipers about 6 inches and knock them on the bench until the distance of 3 inches is obtained. If they are opened too far, close them as nearly as possible to the size required, using the fingers; then if they require further adjusting, tap lightly to the required size; this prevents the legs and joints from being damaged. As the pointed ends are thin, callipers have a certain amount of springiness, which results in wrong measurements when the callipers are improperly or carelessly used. In large callipers, a difference of a quarter of an inch is sometimes made.

Tell the class that there are many other kinds of callipers, the principal being:—

Scribing Callipers, sometimes called **odd leg callipers**, because one foot is curved, and the other ground to a sharp point and hardened. These are chiefly used for scribing lines parallel to a surface, the curved foot being drawn along the surface as a guide. They are also used for finding the centre of a piece of metal in turning.



SPRING CALLIPERS.

Spring Callipers are made in much the same way as spring dividers. The legs are made in one piece, flattened at the top to form a spring in place of a joint; this tends to keep the legs apart. A screw is secured to one leg, and passes through an oval hole in the other. The legs are closed by means of a wing nut, working upon the screw, and so compressing the spring.

Smiths' Callipers have a long handle on account of the heat.

LESSON XIV

THE SCREW PRESS AND PUNCHING

TAKE a piece of metal, and tell the boys that a square hole is to be filed in the centre. They will hardly be able to say how this is to be done, so the teacher must explain the process to them. They will see that before a file can be used, a hole must be pierced in the metal large enough to admit the file. Tell the class that the quickest method of doing this is to punch the metal out with a **fly or screw press,** sometimes called a **punching machine.**

SCREW PRESS.

Draw the boys round the press, and explain the working. Take the **handle** and press it forward; it will be noticed that this causes the screw to move upward, carrying with it a slide to which is attached a small round piece of steel called a **punch.** Bring the handle back again, and the boys will see that the screw, slide and punch return to their former place.

Put a piece of metal in position and punch a hole. Raise the punch by pressing the handle forward; let the boys notice the piece of metal left behind. Elicit that a small hole, the size of the punch, has been pierced. Remove the piece of metal, and let the boys see

that underneath it is a plate of steel, containing a hole of the same shape and size as the end of the punch which pierced the metal. This plate is called a **die**. The edges of the hole and punch, being sharp, cut through the unsupported metal. Ask the class what has become of the piece of metal which has been punched out. It has passed through into the box below. Refer to the size and shape of the hole left in the metal as being identical with that of the punch and die, and so elicit that if a hole of different shape or size is required the present punch and die must be removed, and others of the required shape inserted in their places. Explain how this is done; the die is secured to the **boss** or **bolster** by means of a **set screw.** When the die is to be removed, the screw is withdrawn and the required die inserted. The boss or bolster holding the die is adjusted by means of four **poppets**. A similar screw to that used for the die secures the punch to the slide. Remove the handle and weight and proceed to turn the screw with the hand. The boys will notice that it is difficult to do this, to give enough pressure to pierce a hole. Replace the handle and weight, and show that the handle forms a kind of **wrench** or **lever**, and so enables sufficient power to be given to the screw to force the punch through the metal. The **ball** is simply a weight which gives additional power to the lever. After the hole has been punched, the metal sometimes adheres so firmly to the punch that a small fork-shaped piece of metal has to be used to dislodge it. Two **stops** and a **plate** prevent the screw from driving the punch too deeply into the die.

The screw press is also used for pressing metal into various shapes.

Cast iron and hardened steel are too brittle to be punched or pressed, and holes in these metals must be drilled.

The body and ball of the punch are made of cast iron, the remainder of wrought iron or mild steel. The punches and dies are made of tool steel and should be hardered and tempered to a dark straw.

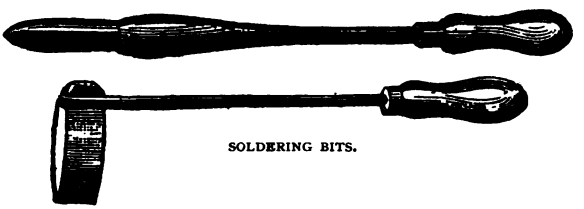
All parts of the press should fit well.

LESSON XV

THE SOLDERING BIT AND SOLDERING

Materials and Tools Required.—Soldering bit, stove for heating, solder, flux (chloride of zinc, resin and oil, or resin) two pieces of iron two pieces of new tin, sal-ammoniac.

Show the class two pieces of iron, and tell them they are to be joined together at right angles. Can any boy suggest a method of doing this? If the correct answer is not given, tell the class that the pieces



SOLDERING BITS.

are to be **soldered.** Ask what is meant by soldering, and explain that it is joining by means of a fusible metallic cement (Lat. *solidus*, solid).

Show the boys a stick of **solder**, and ask them to describe it—a silver-coloured solid. Explain that it is an alloy (two or more metals mixed together) consisting, for ordinary soldering, of two parts tin, and three parts lead, but for special metals, such as pewter, etc., bismuth and mercury are added, to render the solder fusible at a lower temperature. It cannot be applied in its present solid state; therefore it must be reduced to a liquid form.

Now explain that it must be melted with a tool called a **soldering bit**, which is heated in a stove or fire, only sufficiently to melt the

solder. Let the class examine the soldering bit, and draw from them that it is composed of a copper bit riveted or bolted to an iron shaft, and secured by a wooden handle which prevents the heat being carried to the hand. The end used for soldering is made of copper, because this metal retains the heat longer than iron or steel. Show, by applying the warm soldering bit to the solder, that although it melts the solder, the latter will not adhere to the iron or bit. This is due to the oxide which has accumulated on the surfaces, and which must be removed by scraping or filing until the metal becomes bright. Apply the solder to the brightened surfaces, and show that something more must be done, as the solder will only adhere in places.

HEATING STOVE.

Tell the boys that the soldering bit must be **tinned**, and explain the process. Heat the bit just enough to melt the solder, and file the point bright with an old file, afterwards rubbing it on a piece of sal-ammoniac to prevent the formation of oxide. Rub the bit on the solder, which will now readily adhere. Zinc chloride may be used in the place of sal-ammoniac if desired. Show, by experiment, that tinning the bit is not sufficient, as the solder still adheres in patches. This is due to the oxygen in the atmosphere acting upon the iron and warm solder, crusting or oxidising the latter before it can unite with the iron.

Something must therefore be used to make the solder flow more freely. Zinc chloride, resin and oil, or resin alone, have been found well suited for this purpose, and are called **fluxes** (Lat. *fluo*, *fluxum* —to flow).

With the soldering bit tinned, and the iron bright, coat thinly with

a flux, and show how to tin the iron by rubbing it over with the warm soldering bit, occasionally touching the solder, until a coating of solder appears where the joint is to be made. (Warn the class against using too much solder, as it not only is wasteful, but also spoils the appearance of the work.)

When the iron has been tinned smear the edges with a flux, and proceed to join the two pieces. Place one piece of metal on the bench, and hold the other at right angles with a pair of pliers or an old duster to prevent the fingers being burnt. Touch with the soldering bit in one or two places, using a small quantity of solder. The bit will now want re-heating. Care should be taken not to overheat it, or the solder on the end will be burnt off, and re-tinning will be required. The bit should never be allowed to get red hot, but only hot enough to melt the solder. A clear fire, or gas stove, should be used for heating. When the bit is taken out of the fire, it should be rubbed on a piece of paper placed upon the floor to prevent any dust being carried to the work. Place the point of the soldering bit into the seam and draw very slowly, using only sufficient solder to give a very thin layer. A good plan is to slope the metal while soldering, to enable the solder to flow more readily into the seam.

Show the class two pieces of new tin; they will at once see that these do not require tinning, but explain that the rest of the process for soldering tin is the same as that for soldering iron. Copper and brass are also united in the same manner as iron.

Explain that the metals to be soldered should have a higher melting point than the solder used to join them. When a **corrosive flux** is used the article should afterwards be well washed to remove any surplus flux.

When articles are to be fastened together for turning purposes, or as in Exercise 26, the parts to be united are tinned over and placed in position. The solder is then heated by means of a blow pipe, or red hot iron held over the metal; this is known as **sweating**.

All seams should be well fitting to ensure good soldering.

LESSON XVI

THE DRILLING MACHINE AND DRILLING

SHOW the class a piece of cast iron through which a hole is to be made. Explain that it cannot be punched, as cast iron is too brittle; therefore it must be **drilled.**

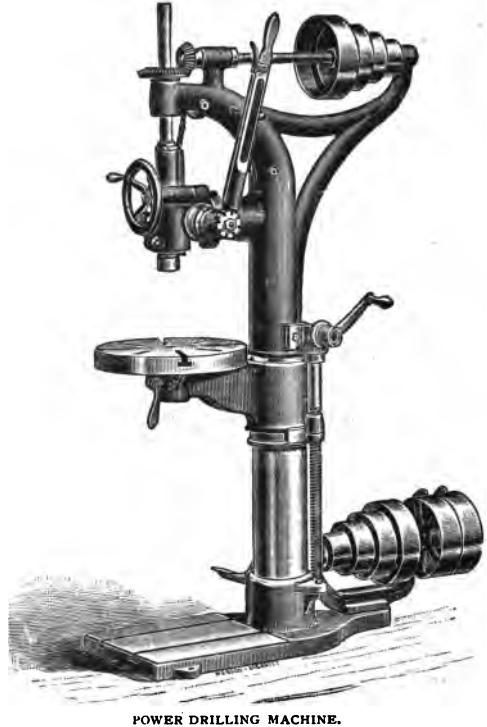
Bring the class round the **drilling machine,** and drill a hole. Explain that the metal is placed upon a cast iron table secured to the **pillar** or **standard** of the machine. In large machines, where work of various sizes is to be drilled, the table is made adjustable. Let the class notice that the table contains a number of holes, and explain that these are used for **bolting** or **clamping** work securely to it while being drilled. In some machines a small vice is attached to the table. To enable the work to rest evenly upon it the surface of the table is made true.

DRILL SOCKET.

Let the boys point out which part of the machine really makes the hole; tell them this is called a **drill.** Turn the machine slowly, and let the class notice that the drill is worked by means of two **bevel wheels**—one is attached to the **spindle** and **socket,** in which the drill is fixed; the other is secured to the **shaft,** to which the power is applied. These wheels cause the drill to revolve. Explain that, as the hole is being drilled, the drill must be gently pressed into the metal to enable it to bite and cut its way through. This pressure is applied by turning a screw or by pressing a lever. The drill is fixed into a socket and sometimes held by a **set screw.**

Elicit that to drill holes of various sizes, larger or smaller drills must

HAND DRILLING MACHINE.



POWER DRILLING MACHINE.

be used, and that the drill must be harder than the metal which is drilled; but not too hard or pieces will chip off.

The smaller the drill, and the softer the metal, the greater the speed at which it works, and *vice versa.*

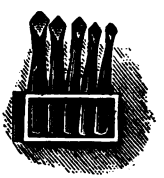
Drills are made of various shapes, from best tool steel. Those most generally used are the **diamond point** or **spear head, twist drill** and **countersink.**

The **diamond point** or **spear head,** so called from its shape, and until recent years the principal drill used, is made from a piece of round or square steel, drawn down to a flat point. To allow the cuttings to escape, the drill is made smaller above the point. The

TAPER SHANK TWIST DRILL.

STRAIGHT SHANK TWIST DRILL.

COUNTERSINK DRILL.



DIAMOND-POINT DRILLS.

cutting edges of the drill are called **lips** or **facets.** To make the drill cut well and accurately the lips should be ground off at the back to give a **clearance angle** of about three degrees. The lips should be equal in length. If one side is longer than the other, the diameter of the hole made will be larger than that of the drill, and all the cutting will be done by the long edge or lip. The objection to the diamond point is that re-grinding alters the diameter of the drill.

The diamond point drill has been replaced to a great extent by the **twist drill.** This drill derives its name from its shape. It is the best form of drill for general use. The drill, being parallel throughout its length, and having the twist uniform, can be repeatedly re-ground without alteration of its diameter. The clearance angles and lips are

ground as for the **diamond point.** The twist allows the cuttings to escape, and so prevents them becoming powdered and wedging the drill. The twist drill is an improvement upon the diamond point, especially for drilling holes in cast iron. The parallel sides of the drill prevent the point running from the denser portion of the metal it is cutting into the opposite side, which may be soft or spongy. Thus a straight hole can be obtained.

Drill a small hole, and fit the screw portion of a screw nail into it; the class will notice that the head projects above the surface of the metal. Comment upon the inconvenience of this; the edges of the head are sharp, and hands and fingers are very liable to come in contact with the edges and become injured. The extra metal above the surface would prevent any other surface fitting close to it, as in the case of door hinges, etc. Ask the boys if they can suggest a method by which this difficulty can be avoided. Show that if the head of the screw were filed or cut off the screw would be useless and drop through. Explain that the mouth of the hole must be enlarged or recessed so that the head can sink into the metal and be flush with the surface. This is known as **countersinking**. Elicit that a drill of a particular shape must be inserted for this purpose. This drill is known as a **countersink drill.** Countersink the hole, and again fit in the screw; let the class see that the screw head sinks into the metal. Elicit that rivet heads are sunk in the same manner (*see* Lesson on "Riveting").

Explain to the class that there are many forms of drills other than those already dealt with. The chief of these are,—

The **pin drill**—used for drilling larger holes and recessing for the heads of nuts, bolts, etc., the pin being inserted in a hole of the same size previously drilled and forming a guide for the larger hole.

The **key way** or **flat drill**—used for making holes for keys and featherways in shafts, etc. The point, being flat, gives a flat-bottomed groove.

When a hole is to be slightly enlarged after drilling, a tool called a **reamer** is used. Its shape resembles that of a tap, with flutes or grooves. It is worked by means of a lever or wrench, and in a similar manner to that of taps and wrenches.

Explain to the boys that when a hole is to be drilled a centre dot is made to enable the point to enter the metal, and a circle slightly larger than the hole required is described, so that the operator can more easily see the direction in which the point of the drill is running. Before the drill has cut its full diameter the work should be tested, and if the drill is running out of centre a short groove should be made with a round-nosed chisel in the direction in which the point of the drill is required to work. The groove will cause the point of the drill to work into it, thus altering its course. This is known as **drawing over** a hole and should be repeated until the drill runs truly with the described circle.

REAMER.

When a piece of work is to be placed between the centres of a lathe a small hole is drilled, and afterwards countersunk, to fit the taper of the lathe centre, so as to ensure the work being turned truly.

LESSON XVII

PLIERS

A PIECE of thin strip iron is to be bent into various shapes. Show that if it is too stiff to be bent with the fingers a pair of **pliers** must be used.

Let the class examine the pliers, and elicit that they are composed of two pieces of steel riveted together so as to form a double lever. The longer ends form the handles; the shorter ends, which are slightly hardened to withstand the wear from the hard metals, are made in various shapes according to the purpose for which they are intended.

FLAT-NOSED PLIERS.

ROUND-NOSED PLIERS.

Bend a piece of metal with the pliers, and explain that the metal should be held in the left hand, and the pliers in the right. The pliers should grasp the extreme end of the metal, which should be bent away from the body.

There are several kinds of pliers, but those most generally used are the **round** and **flat-nosed**—so called from their shape. The **flat-nosed** pliers are used for holding, twisting and straightening metal, or bending it at right angles. The **round-nosed** pliers are used for bending metal into curved forms.

LESSON XVIII

RIVETING

TAKE two pieces of metal, and tell the class they are to be joined together to form a strong joint. Ask them how this can be done. Explain that soldering is not strong enough. Tell the class that the two pieces are to be joined together by means of **rivets.**

Show the boys a rivet, and elicit that it is a small piece of round metal, with a cup-shaped head at one end, that to hold the two pieces of metal together the rivets must pass through both pieces, and that holes must be drilled or punched in the metal to allow the rivets to pass through. The boys will also see that the two pieces must overlap, and that the holes in each piece must be exactly over each other.

Pass the rivet through the two pieces of metal: the class will notice that the pieces are still loose, and would come apart; elicit that another head must therefore be formed. Show that the rivet must be long enough to leave a small portion projecting beyond the plates, to form another head. This process is called **riveting.**

Rivet the two pieces together and explain the process. Pass the rivet through the metal, with the head on the under side. To hold the head of the rivet firmly against the metal while riveting, place the head into a small die of the same shape held in the vice. With the ball pane of an engineer's hammer strike the tail of the rivet. This causes the metal to spread and burr over, so forming another head. This head is then finished by means of a cup-shaped die called a **snap.**

Show the boys that the pieces of metal cannot be taken apart without filing or cutting off one head; rivets, therefore, can only be used when the fastening is to be permanent.

Explain that the holes must be made just large enough to allow the rivet to pass through. To ensure the plates being drawn tightly together the rivets are heated white hot, and hammered down immediately. In cooling, the rivets contract and so pull the plates tightly together.

Explain that sufficient metal should be left between the holes and the edges of the plates to prevent the metal cracking.

It is sometimes necessary to have the heads of the rivets flush with the metal. Explain that if the heads were cut close to the plates, the rivets would drop out; therefore, the head must still remain on the rivet, though it must not be allowed to project. Ask for any method of overcoming the difficulty. Explain that the hole is enlarged conically to enable the head to sink down into the metal and so be on a level with its surface. This is called **countersinking** (*see* "Drilling").

Rivets are made of brass, copper, iron and steel, according to the uses to which they are to be put.

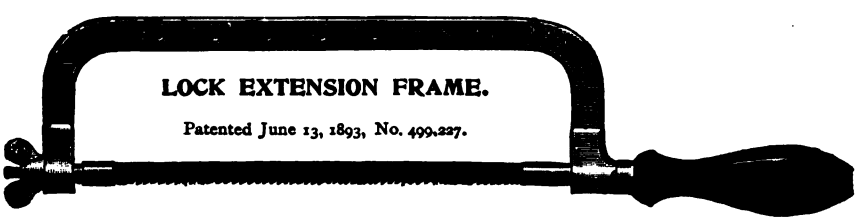
If a rivet is too long and requires filing, great care should be taken to file the end at right angles to the body of the rivet, and the corners should be slightly rounded. If one edge is left longer than the other the metal will tend to spread in that direction, thus forming a badly-shaped head.

LESSON XIX

THE HACKSAW

SHOW the class a piece of iron or brass tube which is to be cut. Elicit that if cut with the shears or chisel the tube would be altered in shape by the edges closing together. Ask if any boy can say how the tube could be cut without the shape being altered: a **hacksaw** must be used.

Let the boys examine the hacksaw and note that it is composed of a steel or iron **frame**, into which a saw **blade** is fixed; one end of the



HACKSAW.

blade is secured to the frame by means of a small hook bolt and wing nut, the other end is secured to the handle, which passes through the frame, by a small staple or pin.

When the blade becomes blunt or broken it can be removed by unscrewing the wing nut, and a new one inserted. Explain that the saw blade must be screwed tightly; if left slack it will twist and break.

Some frames are adjustable in length, so that blades of different sizes can be used.

Let the boys examine the blade; it is a long, narrow, thin blade of

hardened tool steel, with small triangular teeth, numbering about 23 or 24 per inch. A small hole at each end allows the pins to pass through to secure the blade.

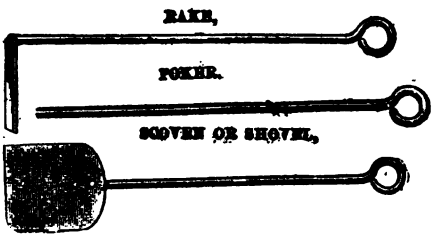
Cut a portion of the tube and let the boys notice **how the saw is used**. The handle is grasped in the right hand, and the saw is guided by the left, in a similar manner to the file. In using the saw the blade should not be twisted. As in the file, the pressure should be applied on the **forward** stroke only, and, also as in the file, the teeth of the saw slope only in one direction, and will therefore only cut in that direction. In fixing the blade care should be taken to see that the teeth slope **from** the handle so that the cutting may be done in a **forward direction**.

LESSON XX

THE FORGE AND FORGING

BRING the class round the forge and let them examine its structure. Elicit that it is composed of a cast iron frame, lined with firebrick. Some forges are made of firebrick, and built into the wall, a chimney with a hood carrying away the fumes and smoke.

Let the boys point out in which part of the forge the fire is made. Tell them it is called the **hearth**. Draw attention to the small pipe which is usually fixed into the back of the fire, and a few inches above the hearth. The boys can easily trace its connection with the bellows; the **bellows** are used to blow blasts of air into the fire to aid combustion, and are placed either under, at the side, or at the back of the forge, and are worked either by hand or treadle. In most modern workshops, a **fan** or **blower** is used.



Point out the fire-irons which are used in connection with the forge —the **poker**, the **slice**, and the **rake**.

The **poker** has a hook at one end, used for cleaning away the clinker. The **slice** (a small flat shovel or spade) is used for putting small quantities of coal on the fire and for packing it into place while the fire is burning. The **rake** is a rod of iron or steel, one end of which is formed into a handle, and the other end is flattened out and bent at right angles. It is used to rake the fuel around the metal which is being heated.

FORGE (FAN).

FORGE (BELLOWS).

Let the boys again notice the small pipe at the back of the forge. Tell them it is called a **tuyere** or **twyer**, and that the part which has been thickened, to withstand as much as possible the fierce heat to which it is subjected, is called the **nozzle**. When this eventually burns away it can be replaced.

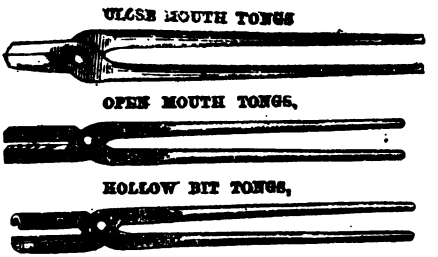
In all large forges, which have a very powerful blast, the tuyere is surrounded with water, either in a tank or pipes, to prevent it becoming heated or melted.

Show the boys how to make a fire. Lay paper and sticks upon the hearth, close to the tuyere; cover and surround with small pieces of coke or coal. Light the fire, and explain that a small blast should be started to make it burn well. The blast is increased as the fire burns. If too strong a blast is given at first it will blow the fire out. Show the boys that the hottest part of the fire is immediately over and in front of the tuyere.

Take a piece of metal, and show the boys how and where to place it: the portion to be heated, should be put in the hottest part of the fire, but the blast should not be allowed to act directly upon it. A little fuel should be placed between the tuyere and the iron. Explain that as the fuel burns some parts of it become liquid, and do not burn away, but settle to the bottom; this is known as **slag** or **clinker**. If the iron is placed too low in the fire, it will rest upon the slag, which will adhere to it, and when the metal is hammered give it a pitted appearance. There is no advantage in having a large fire; it causes a waste of fuel and is inconvenient to the workman. To keep the fire small the outside edges of the fuel are kept damp. The fire should be kept as free as possible from slag, which accumulates and reaches the iron. This is removed with the poker. The blast must be regulated according to the work.

Explain that when wrought iron is to be hammered or beaten out it should be heated to a white heat, so that the particles may adhere more firmly. If the iron is only heated to a red heat, it will tend to split or crack. Cast steel should never be heated beyond a blood-red, or the carbon will be burnt out and the steel rendered useless for tools (*see* Lesson on "Hardening").

Small pieces of metal should always be held with a pair of **tongs**. The boys will see that the tongs vary in shape and size, according to their use. Those most generally used are the **flat, hollow** and **pincer** tongs.

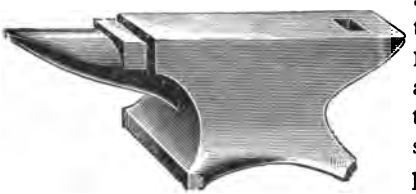


The **flat tongs** are used for gripping flat pieces of metal.

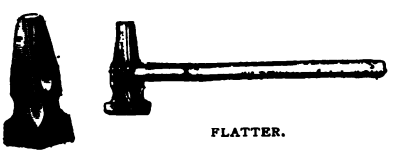
The **hollow bit tongs** are for holding rods or bars, and grip for a distance of about 2 inches.

The **pincer tongs** are used when one end of the metal is enlarged as in the case of a bolt, etc.

Explain that when gripping a heavy piece of metal with the tongs, a ring of metal is slipped over the ends of the handles or **reins**, and gently tapped with a hammer. This causes the tongs to bite securely without strain or further effort on the part of the workman. The ring is called a **coupler**.

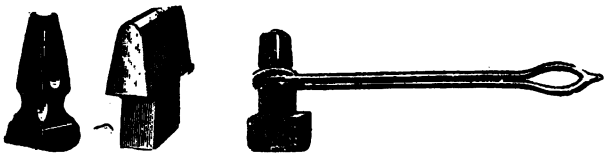

ANVIL.

Whenever hot iron is to be hammered out it must be hammered upon another piece of metal, generally an **anvil**. This process is known as **forging**. By forging metal we mean raising it to a high temperature, making it red or white hot, and hammering it into any shape which may be required. The shaping should be done as quickly as possible.


FLATTER.

The anvil consists of a heavy block of wrought iron, with a thin layer of steel welded to it and forming the **face**; this gives a harder surface, which will wear longer than iron. Let the boys notice that one

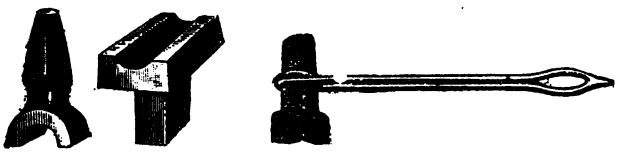
edge of the face is rounded, and the other square. This gives a round or square corner when metal is struck upon it. Let them also notice the long pointed end of the anvil, called the **beak** or **pike**; this is used for turning iron into curved shapes, and for welding rings, hoops, etc. The small holes at the opposite end, into which an **anvil cutter**,



TOP AND BOTTOM FULLERS.

or **hardie**, or small **bottom tools** are placed, are used for forming the heads of bolts, etc. The anvil is fixed upon a wood or iron block, and secured by spikes or staples. Emphasise the fact that **the anvil is one of the most essential tools in the workshop.**

Tell the boys that, when a piece of metal is to be flattened, a tool with a wide, flat face, somewhat resembling a hammer is used; this is called a **flatter** or **set hammer**. It is held upon the metal by a rod or wooden handle, while a second person strikes it with a sledge hammer. When a piece of metal is to be **drawn down**, the point rests upon the anvil, with the opposite end slightly raised. The blows are directed



TOP AND BOTTOM SWAGES.

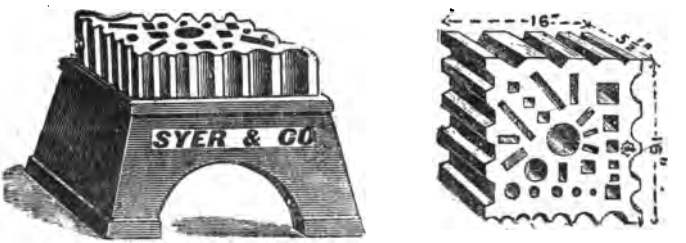
upon the point or lower portion. The metal should be occasionally turned over to ensure uniformity. This draws down and elongates the metal.

If a piece of metal is to be thickened at the end the portion to be thickened is heated almost to a welding point, the bar is then held vertically and the heated end jumped upon the anvil, or the bar is held hori-

zontally and hammered. This is known as **jumping** or **upsetting** the metal.

If a groove is to be made in a piece of metal, tools called **fullers** are used. These tools are somewhat similar to chisels, with points of various shapes.

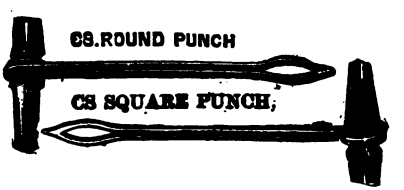
When a piece of metal is to be shaped, having a corresponding groove top and bottom, two fullers are used, one, known as the **bottom**



SWAGE BLOCK.

fuller, being fixed into the square hole in the face of the anvil, while the other, the **top fuller**, is held by means of a rod. The metal is placed between the two. A second person strikes the head of the top fuller with a sledge hammer.

When a piece of metal is to be rounded, it is hammered as nearly as possible into shape. It is then placed between two round tools called **swages**, or **rounding tools**. The bottom swage is fitted into the anvil, and the blows are dealt upon the top swage.



Explain that swages are of various shapes—round, square, oblong, hexagonal, etc., according to the shape into which the metal is to be worked.

Tell the boys that when a piece of hot metal is to be shaped quickly and accurately, a **swage block** is used. This consists of a block of metal, pierced with numerous holes, round, square, oblong, etc.—and

its edges are provided with grooves of various sizes, and of circular, hexagonal, V, or other shape.

When a hole is to be made in the hot metal, a **round** or **square punch** is used, in a similar manner to a rod chisel, and the metal placed over a corresponding hole in the swage block.

ANVIL CUTTER.

When a smith, working single-handed, requires to cut a bar or rod of metal he uses an **anvil cutter**. This is a piece of steel similar to the "point" of a chisel, and fixed into the square hole in the anvil. The metal is laid upon it and struck; this causes a nick to be formed on the under side. The metal is then turned, and the operation repeated until all sides are nicked, when the bar usually flies into two pieces.

For cooling hot metal a cast iron **water trough** is provided.

LESSON XXI

THE GRINDSTONE AND GRINDING

TAKE a cold flat chisel which requires sharpening. Explain that as it is made of hardened steel it is too hard to file, and must therefore be ground.

Call the class round the grindstone and let them examine it. Elicit that it consists of a **wheel of sandstone,** mounted on a revolving axle supported upon a wooden or iron frame. The stone is revolved by hand, treadle, or other power.

GRINDSTONE.

Explain that in order to cut well, the stone should be of a rather coarse but uniform grain. It should not be hard or flinty.

Elicit from the class that when the stone is revolved against the chisel this becomes heated. Explain that the steel is thereby softened and its temper destroyed. To remedy this water is poured upon the stone. To prevent the water splashing the floor and operator a **trough** and **hood** are generally provided. The stone should never be allowed to rest in water, as this softens it and causes it to wear unevenly.

Grind the cutting edge of the chisel, and show the class that, in order to support the tool while grinding, a small bar, called **a rest,** is attached to the frame, and should be kept close up to the stone, especially when the stone is revolving towards the operator. Explain that in grinding the best results are obtained when the stone is revolving towards the operator. Show the boys the dangers of this to an inexperienced workman; also show them that almost as good results can be obtained by revolving the stone away from the operator; the latter method is also cleaner, the splashes and dust following the stone. Impress upon the boys that any grinding they may have to do must always be done with the stone revolving **away from** the tool which they are holding, and away from themselves.

Explain that the tool should be held and guided with both hands.

To prevent the stone becoming unevenly worn the tool is sometimes passed across the face of the stone from side to side while it is being ground.

After a cutting tool has been ground, the edges should be finished off upon an oil stone, to give a keener edge.

Neither the oilstone nor the grindstone should ever be used dry.

The **bevels** and **facets** of the tools can be regulated by raising or lowering the handle of the tool.

Particular care should be taken of the grindstone if good work is to result. If left exposed to the weather or to the direct rays of the sun the stone becomes very hard. When the surface becomes unevenly worn, it must be trued over. This is done by means of a pointed piece of hardened steel, usually an old file. There is also a special machine for this purpose, having an adjustable screw or worm which revolves as the stone revolves and so trues the surface.

LESSON XXII

STOCKS AND DIES—TAPS AND WRENCHES

SHOW the class a screw and corresponding nut, and let the boys examine them. Elicit that they have corresponding grooves cut in them, leaving a projection known as a **thread**. Explain that these vary in shape and number, according to the size and particular purpose for which they are required, also that the nut must be made first, and the screw made to fit the nut.

TAPER TAP.

Take a piece of round iron of the diameter of the screw to be cut, and a blank nut. Explain that a hole must be drilled in the nut, to allow the tool which forms the thread to enter, and that if this hole were made of the same size as the piece of round iron, or **blank** as it is called, upon which the screw is to be cut, it would simply slip through; therefore, a hole of a slightly smaller diameter must be drilled. Show the class the tool used for cutting the thread in the nut; it is called a **tap**. Elicit that it is a screw slightly tapering towards the point, with longitudinal grooves or **flutes** to form cutting edges, and is made of hardened and tempered steel. Explain that the taper enables the tap to enter the hole in the nut, and, as it is forced down, gradually to cut the thread.

Secure the nut in the vice, and place the tap in the hole. Show the class that the fingers are not strong enough to turn the tool in the hole, and that a **wrench** is therefore fixed to the square-shaped head of the tap.

Let the boys examine the **tap wrench**, and elicit that it is a plate of steel, pierced with square holes corresponding with the

square heads of the taps, and drawn out and rounded to form a handle at each end. The wrench should fit properly, and hold firmly on the head of the tap. The wrench is grasped in both hands, and

TAP WRENCH.

turned from right to left (clockwise) with a slight downward pressure. The screwing should be continued until the whole of the tap has worked through the hole. If the boys examine the taper tap closely they will notice that the thread is full at the top of the tap, but gradually tapers off, so that the bottom of the tap has very little thread. This allows it to work its way gradually through the hole to be screwed, and as the tap works farther through the hole the depth of thread is increased, until, when the tap is almost through, the full threads at the top cut their way through the nut, and complete the screw. Explain that, as the tap is forced or wrenched through the hole, the friction causes the tap to become heated. To prevent this, oil is poured round the tap, and so keeps it cool.

PLUG TAPS.

Sometimes a thread has to be made in a nut with only one open end. The other end, being closed, does not allow the taper tap to pass through, so that the full thread cannot be worked into the nut. In such a case, a **plug tap** is used. This cuts a full thread for almost the whole of its length. This tap is also used when a taper tap is not long enough to work entirely through a hole.

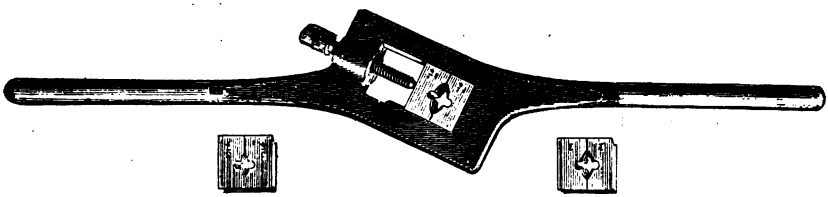
For tapping very small holes a **ring tap** is used. Portions of the screwed end are filed flat, to form the cutting edges. The ring enables the tap to be grasped firmly and sufficient pressure to be put upon it without the aid of a wrench.

Threads or screws which are cut with the aid of a tap are known as **internal threads.**

Tell the class that the drilled hole must be perfectly straight, or the tap is liable to be broken.

Proceed now to cut the thread upon the piece of round iron, or blank, to form a screw to fit the nut just made. Explain that for this screw, the threads must be cut by **stocks and dies.** Let the boys examine these tools and show them that the die which cuts the thread is a piece of flat steel, made in halves, and having a thread cut in the middle. It resembles a nut cut in halves, with two small slots to form cutting edges.

The die is placed in a **stock** or **holder**, having an adjustable screw, which enables the dies to be forced into the blank.



STOCKS AND DIES.

Dies are of many shapes, those already described being known as **split dies.**

Solid dies are made in one piece, with slots to form the cutting edges.

The adjusting screw enables the same stock to be used for dies of various sizes.

The blank should first be filed round, to remove all scale and skin, which would be likely to injure the dies, and the end should be slightly bevelled to give the die a grip or start. The blank is then placed either horizontally or vertically in the vice, the latter position being preferable. The dies are opened and dropped over the blank. The screw is tightened so that the teeth are slightly forced into the blank. This is known as the **cut.** If too heavy a cut is put on, the blank will be wrenched or twisted off. The stocks are grasped by the handles

(one in each hand) and worked round horizontally, with a slight downward pressure. The stocks should be turned in the same direction as the screw to be cut—in this case from right to left (clockwise).

When the desired length has been screwed, the dies are worked in the reverse direction to the top of the screw. The dies are then oiled, tightened up, and worked down as before. This should be repeated until the required depth of thread is obtained. The nut should be repeatedly tried upon the screw, until a proper fit is made. Plenty of oil should be used, to enable the dies to be kept cool. The adjusting screw should only be tightened at the top or start of the thread. If the dies are forced downwards when cutting, a bad thread will result.

Small screws are sometimes cut by a **screw plate**. This is a plate of hardened steel, containing a number of drilled and tapped holes of various diameters. Small slots are cut at the sides to form cutting edges for the threads. The threads are produced more by pressure than by cutting, and are cut to the full depth as the plate is worked down the blank.

SCREW PLATE.

Threads cut with stocks and dies, or a screw plate, are known as **external threads**.

Briefly mention to the boys that screws are also cut in the lathe.

When the taps are to be hardened they are placed in iron tubes large enough to admit the tongs to withdraw them. The taps are heated very slowly to a dull red. If heated too quickly the edges of the thread, being thinner, will become heated before the inner portions, and will consequently become burnt. When the taps are of a dull-red colour they are plunged into water and held in an upright position until quite cold. Sometimes the taps are hardened in linseed oil, and the threads coated with yeast or soft soap to protect them while heating. When the taps are cold the flutes or grooves are brightened, and the tap re-

turned to the tube and tempered, or heated to a light straw and afterwards cooled.

Dies are coated with a mixture of soap and oil, and are heated to a cherry red, and afterwards immersed in salt water. In tempering, the dies are polished and placed upon a plate of hot iron, and repeatedly turned until they become a straw colour; they are afterwards cooled in oil.

LESSON XXIII

THE LATHE (SUITABLE FOR METAL TURNING)

DRAW the class round the lathe and explain the use and working of the various parts.

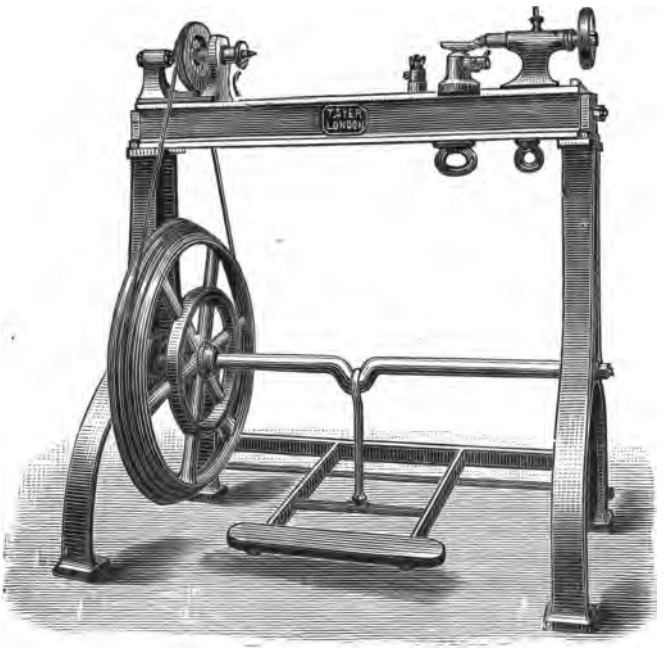
The lathe is a machine for turning and shaping various materials, such as wood, metals, etc., and is worked by treadle or "power." It consists of two upright **standards** supporting a **bed plate**, to which is secured **a fast headstock, loose** or **movable headstock** (sometimes called a **poppet**) and a **tool rest.**

The upright **standards,** being used to support the bed, etc., are made of cast iron, and may be made of any height, to suit the workmen.

The **bed plate** may be made of any required length, and is firmly bolted to the upright standards; it should be made of cast iron, as this metal is rigid and when planed over gives a very smooth surface; the graphite in the iron, by making the surface slippery, greatly assists the loose headstock and tool rest to slide along when required, whereas if wrought iron were used it would cause sticking and, consequently, trouble. The upper surface of the bed plate is planed and made perfectly true, to allow the loose headstock and rest to slide or move truly along it. Sometimes the bed is grooved to allow the rest to be secured and the headstocks adjusted.

The **fast headstock**, as its name implies, is permanently bolted to the bed. It consists of a cast iron frame forming bearings for a **speed pulley** or **cone** and for **gear wheels**, the whole being secured to a **steel spindle** called a **mandrel.** The **speed pulleys** or **stepped cones** (so called from their shape) are arranged to give different speeds

in conjunction with a corresponding set of pulleys, varying in size, and arranged so that the large pulley of the driving shaft can be connected by a belt with the small pulley of the lathe mandrel. A variety of speeds



LATHE.

is obtained by moving the belt from one pulley to another of different size.

The **mandrel** is hollow and screwed at one end to allow a **chuck** or **driving plate** to be secured to it.

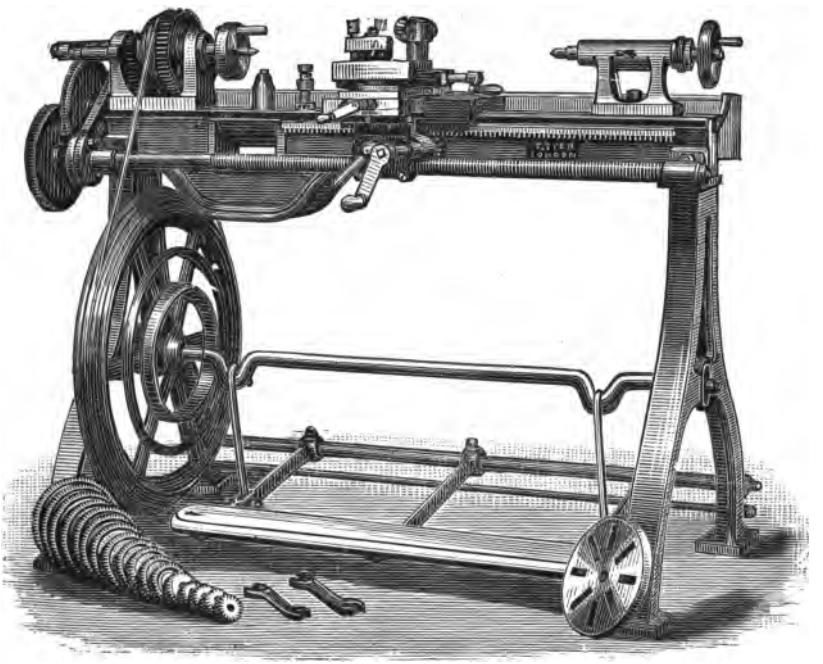
The **movable headstock**, as its name implies, can be moved along the bed plate in either direction. It consists of a cast iron body, with a **barrel** and **screw** having a small handwheel fitted to the screw. To allow the work to be adjusted the loose headstock is moved along

the bed and secured by a bolt. For any auxiliary adjustment the barrel holding the steel centre is extended by turning the small handwheel.

Before the work can be fixed in the lathe the ends must be filed flat and square, and the centre of each end found by the aid of a pair of odd leg callipers. If the work is round, it is sometimes placed on a **V-block**, and a scribing block used to find the centres. This is done by turning the work on the V-block and scribing lines on the ends, the centre being the point at which the lines cut each other; or a **centre square** is used. When the centres have been found, a centre dot is made at each end, and the metal placed between the centres of the lathe to test it. A piece of chalk is held in one hand close to the work, which is spun round on the centres with the other hand. The chalk, taking the place of the tool, will mark where the tool would cut. If the centres are true a chalk line will be made round the work. If untrue, the chalk will mark only in one place, and the centres should be altered, bringing them a little nearer the chalked part; this should be repeated until the centres are correctly found. When this is done the ends are drilled with a **countersink drill**, giving conically-shaped holes corresponding with the centres of the lathe. This is known as **centreing**, and is one of the most important points of good work. Emphasise the fact that badly centred work gives trouble in many ways, viz., (1) the work may run out of truth when finishing; (2) if the centres are not true, a quantity of metal will have to be turned off on one side, and probably, by the time the work is trued, the diameter will be too small for the article required. The ends should be nicely squared so as to revolve truly on the centres. The extreme points of the lathe centres should not touch the extreme points of the conical holes in the ends of the work, or inaccuracies may result. If the metal to be turned is at all bent it should be straightened before centreing and turning.

Adjust the work between the centres of the lathe, and set the lathe in motion. The class will notice that, although the lathe revolves, the work remains stationary. Elicit that something more must be added to carry the work round;—a **carrier**. Draw from the class that the carrier must be secured to the end of the work nearest the **driving plate** which strikes the carrier and thus revolves the work.

Explain that in order to cut the metal a tool or **cutter** of hardened and tempered steel must be held against the work while it is revolved. Let the class examine some lathe tools, and point out that these taper from the cutting edges towards the body. This taper is known as the



SCREW-CUTTING LATHE.

rake of the tool, and varies according to the hardness of the metals. Explain that a rake is ground on the top as well as at the sides and end to give the required keenness. When a soft and fibrous metal, like wrought iron, is to be cut, more rake is required than for cast iron or steel, while for brass a keener edge still is required. Other tools are suitably ground for cutting curves and other shapes.

Put the lathe in motion, and hold a tool near the work; the class will readily see that it cannot be held firmly enough with the hands to cut the metal, and that something must therefore be placed to rest the tool upon. Bring the **tool-rest** into position, and explain that the cutting edge of the tool should be held level with the centres of the work. If the tool is to be held on the rest and in position by the hands it is made longer and has a handle attached, so that more power may be obtained and the tool held more firmly. The surface of the rest, upon which the tool works, should be true, and kept close up to the work. This is known as **hand-turning**, and is only suitable for light work.

Many forms of rests are now used in which the tool can be held by means of a **set screw** or screws, and light and heavy work cut with ease.

Let the class examine a **compound slide rest**, and explain the working to them. The rest moves parallel along the bed by means of a small **pinion** attached to a handle working on a **rack**, and also by a long screw called a **leading screw**. A **clamping nut** secures the rest to the screw. The leading screw is driven by wheels geared to the speed cones of the fast headstock. A **cross slide**, worked by a screw and handle, moves an auxiliary slide, which carries the tool giving the necessary cut. The **upper** or **auxiliary slide**, to which the tool is securely bolted, can be rotated, giving an auxiliary movement, when small tapers, etc., are required.

Explain that, when small pieces of work are to be held, and it is impossible to place them between the centres, a tool called a **chuck** is used, having three or more set screws attached to **jaws** and screwed tightly on the work. The work is tested as for centreing, the set screws being moved and tightened in turn until the work runs true. This process is known as **chucking**.

Warn the boys against running the lathe in the wrong direction; it should always run **towards** the tool when cutting, otherwise the edge of the tool will be broken off. Screw-cutting and the more advanced turning have not been included in the above lesson, as these are generally considered too difficult for the average boy, and in many centres a screw-cutting lathe is not provided.

LESSON XXIV

BRAZING OR HARD SOLDERING

CALL the class round the brazier's hearth or forge, and show them a piece of metal bent into the form of a tube. Tell them that the edges are to be strongly joined together, and the seam be made much stronger than by using ordinary solder. Point out that in order to do this the tube must be **brazed**. Explain that brazing is the joining together of two or more pieces of metal by a fusible metallic cement, known as **spelter** (the German word for zinc). Spelter is an alloy of copper and zinc (a fusible brass).

Elicit that, as is the case with solder, spelter must be reduced to a liquid form before use. Explain that it is melted with a tool called a **blow pipe**.

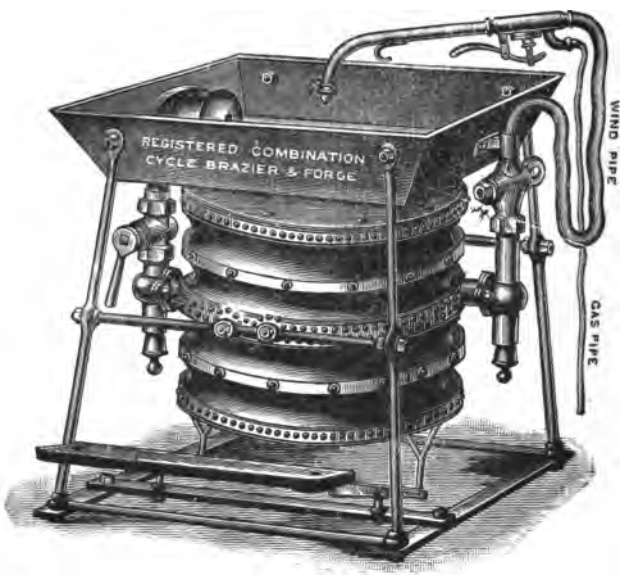
Let the class examine the blow pipe, and elicit that a current of air is passed from the bellows through the pipe. The gas passes through another tube placed in front of the air tube. Show that a valve regulates the supply of air and gas. To prevent the necessity of lighting the gas at the end of each operation, a tiny jet is kept burning. This jet is sufficient to ignite the gas when the valve is opened.

Show the class that, as in soldering, the surfaces to be brazed must be clean and free from oxide, but in brazing, the pieces to be united are bound together with wire and placed into position; this is done to prevent the seam opening when the heated metal expands. Tell the boys that in brazing the metal cannot be held with the fingers as in soldering.

Question the boys concerning the **flux** which is used in soldering,

and tell them that in brazing a flux called **borax** is used with the brass and spelter.

Proceed to braze together the edges of the tube. Place the tube on a piece of flat firebrick, and build pieces of **coke** and **asbestos** around it, leaving a space for the flame to pass through and to add the flux or spelter if required. The tube should have the seam resting upon



BRAZIER (BLOW PIPE).

the bottom, and the flux and spelter should be placed inside, along the seam.

Elicit from the class why coke or asbestos is built around the metal to be brazed. Show that it is done to direct the flame upon the work, and to get more heat. It also effects a saving of gas and of time.

Blow gently at first, to drive off the water of crystallisation from the borax, which will tend to froth and displace the spelter. After the borax has dried increase the heat. When the iron is heated to a dull

red the borax will begin to melt. When it becomes bright red, the spelter will fuse, giving a blue flame, caused by the burning of the zinc.

Tell the boys that if the spelter is not running evenly into the seam, the work should be gently tapped; this will give it the necessary motion.

Explain that, as in soldering, the metals to be brazed should have a higher melting point than the spelter or fusible brass used to unite them.

When brazing a closed tube care should be taken to have a small vent hole, to allow the heated air to escape; otherwise a serious accident may result.

In brazing the spelter should not receive its heat direct from the blow pipe, but should be fused from the heat of the red-hot metal upon which it is resting. Always heat the thickest part first.

After the brazing is completed the joint should be cleaned with a file or **scratch brush.**

All joints should be well fitting to ensure good brazing.

When a blow pipe is not at hand the smith's forge is sometimes used. The objection to this is that the heat cannot be regulated.

When brazing very small work red-hot tongs sometimes take the place of the blow pipe or forge.

LESSON XXV

HARDENING

SHOW the class a piece of tool steel soft enough to be filed; tell them it is to be made exceedingly hard. Explain that this is done by heating the steel to a blood-red, and cooling it quickly. This is known as **hardening**. The more quickly it is cooled, the harder it becomes. Care should be taken that any oxide which has formed while forging is removed before cooling.

Elicit or explain that steel is composed of iron and carbon, and that carbon will burn if heated sufficiently. If steel is heated beyond a blood-red, the carbon burns, and so the quality of the steel is impaired. This is then known as **burnt steel**. Although it will harden, the edge of the tool crumbles and breaks off. Enforce the fact that steel should therefore never be heated beyond a blood-red.

Heat a piece of steel and harden it. Show the class that in this state it cannot be filed, cut or punched. Elicit that any shape which may be required must either be formed before the steel is hardened, or obtained by grinding after hardening.

Case-hardening.—When articles of wrought iron are required to have a hard steely surface they are **case-hardened**. The iron is placed in a case containing substances rich in carbon, such as fragments of horns, bones, leather cuttings, etc.; the box or case is then made air-tight and subjected to a red heat for about twenty-four hours; the fire is allowed to burn out, and the contents of the box are then removed. It will be found that as a result of the burning of the carbonaceous substances a certain quantity of carbon has united with the iron, forming a hard steely skin.

Cast iron cannot be case-hardened.

When small articles are to be case-hardened they are heated to a red heat, then sprinkled with, or rolled in, finely powdered **yellow prussiate** of **potash.** The articles are again heated, and the potash allowed to fuse and spread over the surface; they are then cooled, when the surface will be found to have a hard steely skin.

LESSON XXVI

ANNEALING

TAKE a piece of hardened steel, and show the class that it is too hard to file. Explain that in order to make the steel in a fit condition for filing, it must be heated to a blood-red and allowed to cool very slowly. This process is called **annealing** or **softening**.

The more slowly the steel is cooled the softer it becomes. To enable it to cool very slowly, the steel is immersed while hot in a box of powdered unslaked lime.

Copper, brass, and gun-metal are annealed by heating to a dull or black-red, and cooling in water.

Metals, when hammered or stretched, become brittle, and should be annealed. Stretching of chains, drawing of wire, etc., afford good examples.

LESSON XXVII

THE TEMPERING OF STEEL

EXPLAIN to the class that after steel has been hardened, it is often too hard and brittle to be used for many kinds of work, and that the hardness of steel depends upon the rapidity with which it is cooled.

Show that if a piece of steel is cooled in cold water it would be harder than if cooled in oil; for oil would not draw the heat from the steel so quickly as water.

Explain that if water or any other liquid is heated to a given temperature, and the steel cooled in it, the steel would have the **degree** of **hardness** or **temper** corresponding to that temperature.

For the majority of tools this method of tempering by heated liquids would be too costly and too slow, as almost all the various tools are tempered at a different degree of heat, so that a different receptacle and particular temperature of liquid would be required for each variety of tool.

A process has been discovered by which nature indicates the degree of heat which the steel has reached. It has been found that steel hardened, and afterwards polished, if gradually heated produces a **band of colours** on the polished surface, varying from a light-straw yellow to a pale blue with a tinge of green, **each colour indicating a certain degree of hardness**; if the steel is immediately cooled on the appearance of any one of these colours, it will remain at the degree of hardness or temper which corresponds to that colour. The oxygen acting upon the heated metal causes a thin film of oxide to appear on the surface; this film becomes thicker and changes colour as the heat or temperature of the metal increases. The **colours**,

therefore, **indicate** the **temperature to which the steel has been raised.**

In most lathe tools the cutting edge only should be hardened and tempered; the lower part should be as tough as possible, to resist the pressure put upon the tool in cutting. In tempering a tool of this description the cutting edge should first be heated to a blood-red and cooled quickly (hardened), and afterwards rubbed bright. It is now too hard for most work, therefore its degree of hardness should be lowered in the following manner—upon a piece of red-hot metal or other material lay the tool with its polished side uppermost. As the heat travels upwards through the tool the colours slowly appear upon the surface; when the required temperature is reached, which in this case is indicated by a light-straw colour, the tool is immediately cooled. It will be found that the bottom portion of the tool, which has absorbed more heat than the cutting edge, will be softer or tougher than the polished surface.

Sometimes a process known as **point hardening** is used; this is hardening and tempering in one operation as for a chisel. The chisel to be hardened and tempered by this process is first heated to a blood-red for a distance of about 2 inches, commencing at the cutting edge; the end is then cooled for a distance of 1 inch, leaving sufficient heat in the remaining heated portion to temper or lower the degree of hardness at the cutting edge. The hardened end is rubbed bright with a piece of grit stone, and the heat, travelling towards this end, is indicated by the gradual appearance of the band of colours. These colours must be carefully watched until the requisite colour appears at the cutting edge, which in this case is purple. The tool is immediately cooled.

Below is given a list of colours to which various tools are tempered.

Temper Colour.	*Names of Tools to be Tempered.*
Light grey (exceedingly hard)	Lathe tools, etc., for cutting chilled castings, files, etc.
Light straw . .	Lathe tools, taps, dies, etc.

Temper Colour.	*Names of Tools to be Tempered.*
Dark straw	Dies and punches for screw press.
Brownish yellow	Centre punches, scribers, shear blades, carpenter's chisels, etc.
Reddish brown	
Purple	Large shear blades, table knives, cold sets, chisels, etc.
Blue	Springs, saws, etc.
Light blue	Very rarely used
Bluish green	Do.

LESSON XXVIII

WELDING

SHOW the class two short bars of wrought iron which are to be united together to form one longer bar. Explain that this can be done by a process known as **welding**.

By welding is meant the uniting of wrought iron or mild steel by intense heat. The ability to be united by this means is one of the most useful and important properties of these two metals.

For welding wrought iron the ends to be united should be heated and thickened by **upsetting**, and then slightly flattened; this is known as **scarfing**. Sometimes one end of the bar is split, and the other flattened and slipped into it: this allows the two ends to be joined together without making it thinner by hammering, and so keeps the bar uniform throughout its length.

During the heating the parts to be united are sprinkled with sand, which, on melting, forms a glassy covering, which protects the exterior of the iron from the sulphur present in the fire, and from becoming burnt and oxidised.

At a welding heat the iron is in an exceedingly pasty condition, and when two pieces are pressed or hammered together they will readily unite.

The **weld** must be made quickly, and all the joining done in the first few seconds or the joint will show. It is useless to hammer the iron after the welding heat has left the surface. The actual join or weld must be made at one heat. The metal is usually heated again to a white heat before it is hammered into shape. A good weld should be scarcely discernible even to a critical eye.

For welding, wrought iron requires a much greater heat than steel. At welding heat iron is of a dazzling whiteness and gives off numerous sparks ; steel only shows a deep yellow and emits few sparks.

The work should be lifted out of the fire, and not dragged along the cinders. Any particles of dirt should be rapidly brushed off. Care should be taken that the metal to be heated is not placed too low in the fire, or particles of slag are likely to adhere and become hammered into the iron.

LESSON XXIX

THE PROPERTIES OF CAST IRON

DRAW the boys' attention to several articles around them made of cast iron. Elicit or explain that each separate article has been **cast.** A mould of sand of the requisite shape and size is prepared, and the molten metal made to flow into it. When cold the metal is taken out, and still retains the shape of the mould. The article is known as a **casting.**

Show, by experiment, that cast iron is **hard** and **brittle.** Explain that it is the **cheapest form** of **usable iron.**

Cast iron is very **easily fused,** and is therefore a most **suitable metal** for **castings.**

Show that it is **not malleable nor flexible,** and consequently is of no use to the blacksmith for forging purposes.

It breaks with a **granular section** showing particles of **graphite, carbon** and **iron.** It is **very rigid,** and will bear a great deal of **compression,** but is **very easily broken** when subjected to shocks or heavy blows. It is therefore suitable for pillars supporting roofs and similar heavy weights. Cast iron is **neither ductile nor tenacious.**

When polished the graphite gives a **slippery surface,** rendering the metal suitable for lathe beds and in other cases where various mechanisms are made to slide along a surface.

If heated to redness, and struck while upon the anvil, the particles of iron crumble and fall away.

In order to render cast iron tough and of a more malleable condition, the castings are placed into a box or crucible together with

powdered peroxide of iron (red hæmatite), or other compound having a large proportion of oxygen, and subjected to a red heat from ten to twelve days according to the size of the articles. Door keys, etc., are treated in this way to render them less brittle and to enable them to be brazed when broken. This process removes a portion of the carbon, sulphur and silicon from the metal, but it cannot be hammered like wrought iron, though its brittleness has been decreased.

LESSON XXX

THE PROPERTIES OF WROUGHT IRON

SHOW the class a piece of wrought iron, and explain that it is cast iron which has been reduced to a liquid and worked—hence the name **wrought** or **worked** iron. By this process the cast iron has been deprived of many of its impurities, such as carbon, silicon, etc., being left as wrought iron—**fibrous** and **tough**.

Show by experiment that when broken wrought iron presents a **fibrous section**.

It is **malleable**; it will **forge**, and **bend** into various shapes; it is **ductile**, and can be **drawn** into fine or coarse **wire**; it is **tenacious**, *i.e.*, it will resist a **stretching force** (hence it is useful for chains, etc.).

Show that, when white hot, wrought iron can be **easily welded**. It is not **easily melted**, and **cannot be cast**.

Wrought iron should be as free as possible from **sulphur**, as even small quantities of this substance render it **unworkable** at a **red heat** and useless for welding, though it may be hammered or rolled in the cold state. Iron in this state is said to be **red-short**.

If wrought iron contains **phosphorus** it cannot well be hammered while cold, and will crack or break, though in some cases it will work well when at a red heat. In this condition iron is said to be **cold-short**.

Wrought iron will not harden if heated and quickly cooled. It **rusts very rapidly**.

LESSON XXXI

THE PROPERTIES OF STEEL

LET the class examine a bar of steel and explain that **steel** is a **compound** of **carbon** and **iron.** Show that it is **malleable,** and can be **forged** or **bent** into any shape required. Explain that it can be made in various degrees of hardness to suit the purpose required. Show that when fractured, hard steel has a **silky appearance** and **very close grain.**

It can be **cast** in a similar manner to cast iron, the **sand moulds** being replaced by those of **cast iron.**

Let the boys compare cast iron and cast steel and note the difference. The grain of steel is very close, whereas cast iron has a looser grain, showing particles of graphite.

Cast steel can be distinguished from wrought iron in the following manner: Heat both metals to redness, and cool quickly. Cast steel will harden, and wrought iron remain soft. They may also be distinguished by sound—cast steel giving a clear ring when struck upon a hard surface, and wrought iron a dull sound.

Cast steel is very **flexible** and **tenacious,** and has a **high degree** of **elasticity.**

Steel is a more **expensive** metal than iron, as it requires more working in its manufacture. It is used for cutting tools and when great strength is required. Steel can also be **forged.**

Mild steel can be bent into various shapes while cold, and is distinguished from wrought iron by bending either in or against the direction of the fibres, whereas wrought iron can only be bent at right angles to the fibres.

LESSON XXXII

THE BLAST FURNACE AND THE MANUFACTURE OF CAST IRON

ELICIT from the class the condition in which the iron ore is obtained from the earth, and that before it can be used it must be freed from the impurities with which it is mixed. There are two methods of doing this—(1) By **pulverising** the ore, and passing it between **magnetic rollers**, which attract and retain the iron; (2) By reducing the ore to a liquid. The latter process is termed the **smelting** of the ironstone, and is the method which we shall discuss.

Before the ore can be smelted it is **roasted** or **calcined**; this is done in **kilns**. A modern kiln consists of wrought iron plates riveted together, forming a casing which is lined with firebrick. The kiln is heated at the bottom by fires of coal, and the heat, rising through the charge, drives off sulphur, carbonic acid and water. The ore is thrown into the open top of the kiln, and works its way downwards, and is withdrawn through a hole or door in the bottom of the kiln. This process does not reduce the ore to a liquid; to do this the roasted ore must be **smelted** in a blast furnace.

Show the boys a diagram of a blast furnace as seen from the outside, also a vertical section. Elicit that from the outside it is in shape somewhat like a chimney with a gallery running round the top.

Draw attention to the sectional diagram: the furnace consists of an **outer stack** constructed of wrought iron plates riveted together, and an **inner casing** of firebrick which can be renewed when necessary without injury to the outer casing. The whole is built on a **base** of **sandstone** (a very refractory material) and supported by a **cast iron ring** and **pillars** of the same material.

Explain to the class that to start the furnace, fire is put in at the bottom. It is then gradually filled with coke, and care is taken that it does not heat too rapidly, very little air being allowed to enter.

The time necessary to bring a blast furnace to the required heat is from ten to twelve days. To avoid the loss of time and money which frequent lighting would incur the furnace is kept "**in blast**" until repairs are needed. When the coke with which the furnace was lighted has burnt through, it gradually sinks to the bottom, and small quantities of ironstone, limestone and coke are continually supplied to keep the furnace full; this is known as the **charge.** The limestone acts as a flux, causing the ironstone to flow more readily from the earthy matters, and being heavier to sink to the bottom of the furnace.

Explain that the furnace is "**fed**" from the top. Draw attention to the **gallery** which runs round the top of the furnace, and explain that it is usually reached either by **lifts,** or by an **inclined railway** up which the iron waggons containing the fuel are run. When the waggon reaches the top the material is thrown into a **hopper.** A **bell** or **cone** can be raised or lowered by means of a **chain** and **lever.** When the cone is thus lowered, the charge resting against it falls into the furnace. The bell then assumes its former position until more material is thrown into the hopper, when the bell is lowered as before. In this way the charging can be done without lowering the temperature to any great extent. The bell and hopper prevent escape and consequent waste of the gases, which are carried off by means of a long tube near the top of the furnace, and are used for heating stoves, boilers, etc.

Let the class notice the shape of the inside of the furnace; it is widest in the middle, and gradually tapers upwards to the top, where the bell and hopper are fixed, and downwards to the lowest part of the furnace where the heat is greatest. The furnace is so shaped as to prevent the molten metal falling in a huge mass upon the **hearth** and probably extinguishing the fire.

Elicit that the iron, being heavier than the limestone and coke, gradually sinks down through the burning fuel, gaining more heat and becoming more liquid as it nears the hottest part of the furnace, through which all the iron must pass before it leaves the furnace. As the liquid

metal falls on the hearth it carries with it a quantity of the fuel and cinders, which, being lighter than the iron, rises in great part to the top, and is drawn off into **cinder tubs** prepared to receive it. This is known as **slag** or **cinder**.

When sufficient metal has accumulated on the hearth, a hole, previously stopped with fireclay and sand which has become baked into a brick, is knocked out by means of a long bar which is struck with a sledge hammer, and the metal rushes out. This hole is called a **tap hole,** and the process **tapping the furnace.**

The molten metal flows along a channel to moulds formed of sand prepared during the smelting of the iron to receive it. The principal channel which conveys the metal to feed the smaller moulds is called a **sow,** and the smaller moulds **pigs**; thus we get the name "**pig iron.**" As the main trough becomes full, a workman plunges a spade into it in the direction of the pig mould into which he wishes the metal to flow; so that all the smaller **pig moulds** are fed from the hot metal which is constantly flowing into the sow.

When all the molten metal has been drawn off, the tap hole is again stopped up with fireclay and sand until more metal is ready.

Refer to the name **blast furnace.** Elicit that to aid or stimulate combustion, a strong blast of air is forced into the furnace at the bottom, causing the fire to burn more rapidly, hence the name **blast** furnace. It has been found that blowing cold air into the furnace, just where it would otherwise be the hottest, lowers the temperature. This difficulty has been overcome by heating the air in hot stoves, which are known as **hot-blast stoves.** To enable the air to be passed into the furnace as hot as possible, the stoves are built close to the furnace. The pipes which convey the hot blast are known as **twyers** or **tuyeres,** and in order that the ends may be preserved from the excessive heat of the furnace, water is kept circulating around them. The hot-blast stoves resemble a blast furnace from the outside; the inside is a mass of chequered brickwork, which becomes heated as the hot gases from the blast furnace are allowed to pass through. By means of small tubes projecting near the bottom and covered at the ends by pieces of glass, the heat of the brickwork can be watched. When it becomes white-

hot the gases are turned off by means of a valve, and the cold air from the blowing engines turned into the stoves; the air, passing through the hot brickwork, becomes heated and is conveyed through the tuyeres direct to the blast furnace. The admission of the cold air cools the brickwork, which is again heated to a white heat by the hot gases from the blast furnace, and the operation described is repeated.

To enable a constant supply of heated air to be passed into the furnace, two or three stoves are required, so that while one stove is heating the cold air from the blowing engine, the other is being heated by the gases to receive a supply of cold air, and so on.

LESSON XXXIII

THE PUDDLING FURNACE AND MANUFACTURE OF WROUGHT IRON

SHOW the class a diagram of a puddling furnace and refer to the manufacture of pig or cast iron. Elicit a brief description of the blast furnace; let the boys recall the shape and compare it with that of the puddling furnace. Explain that the puddling furnace resembles a huge oven of cast iron plates, bolted together, and lined inside with firebrick. The roof is dome-shaped or arched, to reflect the heat of the fire upon the iron. In the blast furnace, the fuel and the iron are put together into the same receptacle, the iron working its way through the fuel to the hearth of the furnace. Explain that in a puddling furnace the fire and iron are quite separate.

Refer to the diagram, and elicit that the furnace consists of three parts: **the fire**, the **receptacle** for holding the metal—called **the bath**—and the **chimney** or **flue**. Show that the chimney is the outlet for the flames and smoke, and as the fire is situated at the opposite end of the furnace, the flames, and consequently the heat, must pass over the metal before it is liberated.

Explain that as the iron works its way through the fuel in the blast furnace, it carries with it a quantity of coke or carbon, and it is this carbon which makes the cast iron so brittle. One of the chief functions of the puddling furnace is to abstract the carbon from the metal; this could not be accomplished if the iron were allowed to mix with the coal.

Show, by diagram, that the fire is separated from the metal bath on one side, and from the flue or chimney on the other, by **bridges** of

firebrick, which also secure the cast iron plate forming the **hearth** or **bed**, under which the air is allowed to circulate freely to keep the plate cool.

The fire is fed through a small hole in the front of the grate. The heat is regulated by a **damper** fixed to the top of the chimney, and raised or lowered by means of chains or rods attached to a lever.

Before the iron is put in, the floor and sides of the bed are covered with a layer of **tap cinder** (previously roasted to drive off the sulphur) known as "**bull dog**." To increase the supply of oxygen the tap cinder is coated or levelled with a soft, **red hæmatite ore** called **puddler's mine**. The iron or charge is put into the furnace through a cast iron door lined with firebrick; this door can be raised or lowered by means of a chain and lever. It contains a small aperture called a **stopper hole**, through which is inserted the **bar** or **puddle** used by the **puddler** (so called because he works or **puddles** the iron) in **rabbling** or **stirring** the iron. The pigs of iron are broken up and thrown into the bed, and the fire raised to its full heat by lifting the damper. In about fifteen minutes the iron is heated, the puddler opens the stopper hole, and moves the pigs about with his puddle so that they may be evenly heated. From the time the iron becomes heated, the temperature of the furnace needs careful attention. In about half an hour the iron is melted. The damper is now lowered and the iron thoroughly stirred or **rabbled** to mix it with the cinder and to bring all parts to an equal state of plasticity. The damper is raised, and a full heat maintained. In about another fifteen minutes the metal begins to swell and rise rapidly. The oxygen from the tap cinder, which constitutes the bottom of the bed, begins to unite with the carbon in the iron, forming carbonic oxide, which, rising to the surface, gives the metal the appearance of **boiling**. During this stage the puddler stirs the metal vigorously from the centre of the bath to the bridges. Particles of malleable iron now begin to float on the slag, like grease on water. The puddler draws these together, and the iron being in a pasty condition, they readily adhere and form into a **ball**. This he places near the bridge while he collects another, and so on, until the whole of the charge has been formed into balls weighing from

70 to 80 lbs. each. The balls are subjected to the full heat of the furnace, to rid them of as much cinder as possible. They are now a soft, spongy mass of malleable iron. The puddler draws them separately to the door of the furnace, and, with a pair of tongs with curved jaws, lifts the ball into an iron truck, or drags it along the floor to the **steam hammer** or **shingling machine**. The door of the furnace is then closed, and the furnace filled with a smoky flame to prevent the other balls being oxidised. The balls are now subjected to pressure from the steam hammer, which welds the particles together into oblong slabs called **blooms**, at the same time driving or squeezing out as much of the cinder or slag as possible. This process is termed **shingling** or **blooming**.

The slabs retain sufficient heat to enable them to be drawn down or elongated into rough bars, 12 inches by 4 inches by 1 inch. If the slabs are intended for use as plates or sheets, they are drawn out from 9 inches to 18 inches wide by passing them through heavy grooved rolls rotated by an engine. The metal is now known as ordinary **malleable** or **wrought iron.**

If iron of a better quality is required the bars are cut up into short lengths, and piled into stacks, averaging 3 feet in length, and from 8 inches to 9 inches square, the plates overlapping each other in order to break the joint, and are held together by a band of iron. The bars are then re-heated in a re-heating furnace, which is somewhat similar in construction to the puddling furnace, and are afterwards rolled out into bars, etc.

If a still better quality is required, the above process is repeated.

Wrought iron is, therefore, pig iron deprived of its impurities, such as carbon, silicon, and phosphorus, by being heated and worked in the puddling furnace, and afterwards hammered and rolled.

It should not contain more than ·25 per cent. of carbon.

LESSON XXXIV

THE MANUFACTURE OF MILD STEEL

EXPLAIN to the class that for some articles tool steel is much too hard and that a softer form of steel known as **mild steel** has to be used. This is manufactured by what is known as the "**Bessemer Process**" (named after the inventor).

The apparatus required is known as the **Bessemer Converter.** It is a circular vessel, usually about 10 feet in height and consists of an outer shell of wrought iron plates securely bolted or riveted together, and lined with a very refractory material, usually **ganister,** which is ground to a fine powder, moistened and rammed between a wooden shell (inserted for the purpose) and the wrought iron frame; the wooden shell is then removed and the ganister carefully dried. Any cracks which may appear are rectified before using.

A number of **twyers** or **tuyeres** (usually about seven) are inserted in the bottom of the converter; these are made of fire-brick, and pierced with small holes, through which the blast is forced. A strong hoop of iron encircles the body of the converter, the arms forming **trunnions** upon which the vessel rotates. A **mouth** or **neck** is fixed to the top of the converter at an angle which prevents to a great extent the ejection of the molten metal, and directs the sparks and flame from the casting pit and workmen.

The inside of the converter is made red-hot by burning in it coke or charcoal, which is afterwards poured out; the vessel is rotated into a horizontal position with the mouth uppermost, and the molten pig iron is then poured in from a ladle or direct from the blast furnace or **cupola,** along a channel of wrought iron lined with ganister or sand.

By charging the converter in this position, the twyers are kept above the molten metal, which, if poured direct upon them, would choke them and render them useless. The blast is now turned on, and the vessel raised to a vertical position, which causes a shower of sparks and graphite to be thrown out. The continual blast prevents the metal settling into the tuyere holes. The metal at once begins to boil violently, and expands, filling the whole of the vessel, and emitting from the mouth showers of burning sparks (slag and iron). The pressure of the blast is gradually decreased; in about fifteen minutes the flames begin to subside, denoting that the process is completed. The carbon has been burnt out, and the silicon and earthy matters separated. The iron is now as liquid as water. The converter is again tilted or rotated into a horizontal position, and, when the tuyeres are above the metal, the blast is shut off and about 8 per cent. of melted spiegeleisen is added to the iron, the insertion of which causes a very luminous flame to be emitted from the mouth of the vessel, accompanied by a loud roaring noise; this furthur indicates that the conversion is complete. The metal is allowed to stand for a few seconds, and is then poured off into a heated **casting ladle.** The slag contained in the metal rises to the top, and helps to retain the heat in the liquid metal, which is now run into **ingot moulds.** As each mould is filled the surface is covered with sand, and the expansion or rising which takes place while cooling is restricted by the use of cast iron plates secured to the tops of the moulds.

As soon as the steel has solidified the cast iron mould is withdrawn by the aid of a huge crane, leaving the casting of steel, which is known as an **ingot.** The ingot is then lifted by means of a crane with special clips and carried to the rolling mills, where it is rolled into rails, bars, etc.

Another process of making steel is known as the **Siemens-Martin.** The bath of this furnace resembles that of a puddling furnace, and is heated by gas and air through regenerators at the bottom. The furnace is charged through three working doors, pig iron being thrown into the bath through the centre door and scrap iron and steel at the side doors. A steady heat is maintained till the charge has become as liquid as water (generally four to five hours).

Samples are now taken out at intervals with small iron ladles, and cooled. The test is afterwards broken and examined to ascertain the malleability and toughness of the metal. As soon as the required quality is obtained spiegeleisen is added, and the metal well stirred. The furnace is then tapped through the tap hole, which is opposite the middle working door, into ladles, and the remainder of the process is similar to that of Bessemer. The advantage of Siemens-Martin steel over Bessemer steel is that its malleability and toughness can be ascertained before being cast, though the process is longer. It is greatly used in the construction of boilers, ships, etc. The addition of spiegeleisen or other substance containing a quantity of manganese, gives body to the metal, and allows it to be welded or hammered without crumbling.

LESSON XXXV

THE MANUFACTURE OF TOOL STEEL

SHOW the class a diagram and sectional view of a **cementation furnace**. Elicit that it is a bottle-shaped structure, and is made of firebrick. The inside consists of a fireplace with two firebrick **troughs** or **boxes** surrounded by flues conveying the heat round the troughs and finding outlets in two short chimneys and thence up the stack. The troughs and fireplace are covered in by a brick arch. A **manhole** is left opposite the ends of the troughs, and through this they are charged. Each trough is first layered with charcoal, upon which a layer of the best selected bars of wrought iron is placed; then another layer of charcoal about ½-inch thick, and upon this a layer of bars, and so on, until the troughs are full, the top layer being charcoal. The troughs are then covered with a mixture of siliceous matter and particles of iron, sometimes the mud from grindstone troughs. The manhole is now built up, leaving two tap holes for the insertion and withdrawal of trial bars, so that the cementation may be tested as the operation proceeds. The whole is plastered up to keep it as air-tight as possible.

The fire is now lighted, and in about two days the conversion begins. The siliceous matter which was thrown over the troughs will have fused and glazed the surface, making the troughs or boxes air-tight. The heat is now kept uniform; this causes the fibres of the iron to expand and so absorb the carbon. The heat is maintained for nine or ten days or longer, according to the quantity of carbon required in the steel. The trial bars are withdrawn at intervals, broken, and the fracture examined. The amount of carbon can be estimated by the white silky appearance denoting the depth to which it has penetrated. At each

withdrawal it will be noticed that the carbon has penetrated more deeply into the iron, until the whole has become impregnated and the process of cementation is complete. The fire is then withdrawn or allowed to burn out. When sufficiently cooled the charge is taken out. As the surfaces of the bars will be found to be covered with blisters, the metal is known as **blister steel.** The bars when placed in the troughs contained not more than ·25 per cent. of carbon, but now they contain from ·5 to 1·5 per cent. according to the length of time the bars were subjected to the cementation. The outer portions of the bars contain more carbon than the inner portion. In order to mix the carbon thoroughly with the iron the bars are broken up into small pieces, and placed in a **crucible**—a special pot made of plumbago and fireclay, and provided with a lid—and subjected to a great heat, which reduces the steel to a liquid. At this stage the metal must be well stirred. It is then poured into cast iron moulds, which are usually made in halves to enable the steel to be more easily removed. The insides of the moulds are generally coated with soot or black-lead to prevent the metal adhering.

When the steel has solidified sufficiently to be taken from the mould it is hammered into bars, and is then known as **cast** or **tool steel.**

Cast steel is sometimes made without the process of cementation. The bars of malleable iron are cut up into small pieces, and put into a crucible with a quantity of charcoal and spiegeleisen, to which a little oxide of manganese is afterwards added; the iron in this way becomes saturated with the carbon. It is afterwards cast in the manner described for cementation.

LESSON XXXVI

THE PROPERTIES OF COPPER, BRASS, TIN, ZINC, AND LEAD

The Properties of Copper.—Let the class examine two pieces of copper—one bright and the other tarnished. Draw from them that copper is of a **reddish brown colour,** and can be **highly polished.** Show that it can be **hammered** and **pressed** into various shapes while cold, proving that it is very **soft** and **malleable.** Let a boy twist and bend a piece of thin copper, and elicit that it is **flexible** and **tenacious.** Show the class a coil of wire, and draw from them the term **ductile.**

Explain that hammering copper or drawing it into wire renders it hard; and that to restore its malleability and ductility it must be **annealed.**

By reference to the lightning conductor, etc., elicit the fact that copper is a **good conductor** of **heat** and **electricity.** Draw attention to the soldering bit, and show that copper is a **good retainer** of **heat.**

Explain that it is not a suitable metal for casting purposes, as it is generally unsound when cast.

Copper will **alloy** well (that is, form a compound) with **zinc** or **tin,** producing **brass, bronze** and **gun-metal.**

Copper **tarnishes readily,** forming a greenish rust called **verdigris.** Impress upon the boys the need for care when using copper; any wound or cut should always be covered, as verdigris is highly poisonous.

Copper **melts** at a **dull white heat.**

It is an **expensive metal,** and is therefore used sparingly.

Copper forms a **good base** for silver-plated articles.

The Properties of Brass.—Show the class a piece of brass and let them describe its colour. Explain that it is an **alloy** or compound of **copper** and **zinc** (sometimes tin is added, which then forms a **(bronze).**

It is not so strong as copper, but is very **fusible**, and therefore useful for **brazing** and **casting** purposes.

It is **softer** than wrought iron or steel, and **wears smoothly** and **quickly** when hard substances rub against it. It does **not heat rapidly by friction**, and is therefore much used for **bearings**, etc., of machines.

It takes a **high polish** and is cheaper than copper; it is largely used for **ornamental purposes.**

Brass can be **rolled** and **hammered** into sheets and drawn into wire; it is, therefore, **malleable, ductile** and **tenacious.**

The Properties of Tin.—Show the class a piece of tin, and elicit that it is a **white silvery metal.** Explain that it is **very soft** and **malleable**, and can be **hammered** or **rolled** into very thin sheets (refer to **tin foil).**

It does not rust like copper and iron, and is **not very tenacious** or **ductile**, but is **fusible** at a **low temperature**, and **alloys well** with **copper, lead** and **iron.** It is therefore useful for **coating** copper and iron to prevent rusting. When alloyed with lead it forms **solder** and **pewter**, and with copper it forms **bronze** and **bell metal.**

Thin sheets of iron coated with tin are known as **tin plate**, and sometimes spoken of as "**tin**" only.

The Properties of Zinc.—Let the boys examine a piece of zinc, and draw from them that it is a **greyish white metal.** It can be **rolled** into sheets, is **malleable** and **moderately flexible.** It is **neither tenacious nor ductile**, and it **volatilises** when heated to a bright red. It **alloys well** with **copper** and **iron**, and **rusts very little**; it is therefore used largely for rain water spouts, tanks, etc.

Iron coated with zinc to prevent rusting is known as **galvanised iron**, and is employed for temporary buildings, roofing, cisterns, etc.

Zinc is also used for batteries for generating electricity.

When alloyed with copper it forms **brass**.

The Properties of Lead.—Draw from the class that lead is a **bluish grey metal, soft** and **heavy**; it can be **bent** and **hammered** into various shapes, *i.e.*, it is **flexible** and **malleable**. Explain that it **melts** at a **low temperature** and can be made into **castings**.

It **rusts little** and **bends easily**, and is therefore suitable for gutters, pipes, roofing, etc.

It **alloys well** with **tin**, forming **solder** and **pewter**.

LESSON XXXVII

THE PRESERVATION OF METALS

DRAW the boys' attention to the manner in which iron and other metals rust. Let them examine a piece of rusty iron wire; they will readily see that the rust has penetrated almost to the centre, causing the iron to be in a rotten condition, and so rendering it useless. Elicit the cause of this and how it may be prevented—some of the boys will probably say by painting, oiling, or greasing. Explain that these are good methods for some kinds of ironwork, but are not always practicable (the insides of saucepans, kettles, etc., for instance). Oil and paint are also very liable to be rubbed or scratched off; something must therefore be used which will be permanent and not affected by the weather; tin and zinc have been found very suitable, as they rust but little, and will unite well with the iron and copper.

When tin is to be used, the iron or copper is first cleaned and made bright (if acid is employed for this purpose, the surplus must be well washed off before the tin touches it), and then passed through a bath of molten tin. The article becomes coated with a thin layer of bright tin, which adheres firmly to the iron or copper. This process is known as **tinning**; if the metal to be coated is in the form of thin sheets it is afterwards known as "**tin plate**." Kettles, cooking utensils, etc., are tinned over in this manner.

If iron, which has been cleaned as for tinning, is passed through a bath of molten zinc, a thin coating adheres to the iron, which is then called **galvanised iron**, and is much used for temporary buildings, roofings of sheds, baths, cisterns, watering cans, etc.

To keep polished brass, copper and steel articles from tarnishing

they are often coated with **lacquer** or **clear varnish**, which, to a great extent, prevents the oxygen and moisture in the atmosphere from attacking them. Articles to be thus treated are first polished and warmed, and the lacquer or varnish is applied with a camel hair brush. The lacquer consists of shellac and methylated spirits.

A method has been found of **oxidising** metals by passing a jet of heated air or steam over them, so forming a thick layer of magnetic oxide which prevents the metal rusting.

LESSON XXXVIII

THE IRON FOUNDRY—CASTING AND MOULDING

SHOW the class a diagram of an iron foundry and cupola furnace. Explain that the floor of the foundry consists of a bed of sand and **loam** (the latter being a mixture of alumina and silica) to a depth varying from four to twelve feet according to the size of castings required; the whole is surrounded by high walls supporting a roof.

The furnace in which the iron is melted is known as a **cupola**, and is erected at one end of the foundry to avoid the chimney being carried through the roof. The cupola is circular in shape and has a stack built of firebrick encircled at intervals with bands of iron to support the brickwork. A tap hole and spout near the bottom of the furnace and inside the foundry enable the iron to be run off as required. A number of **twyers** and pipes convey the blast from the blowing engines to the furnace. The cupola is charged from the outside, a small staging being erected for the purpose about half way up the chimney, and the coke and iron are thrown in through a small opening.

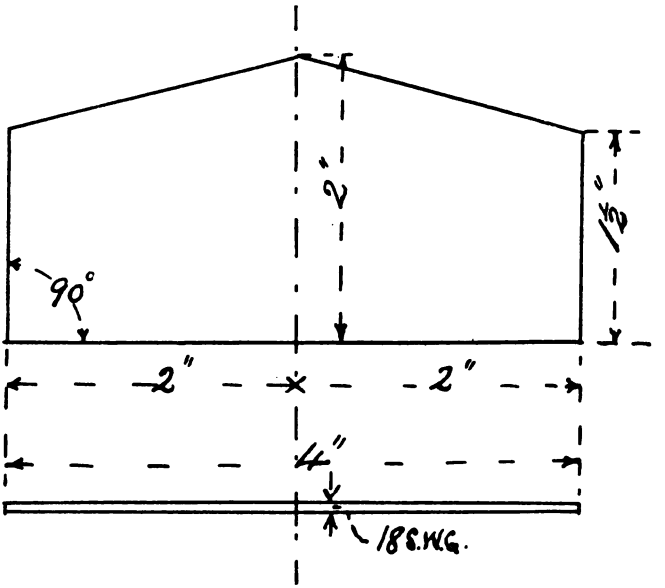
When a casting is to be made, an exact **copy** or **pattern** of the article is first made in wood—yellow pine for large castings and mahogany for small being usually employed. As the heat causes the liquid iron to expand the pattern must be made slightly larger, so that, as the iron contracts in cooling, the casting, when cold, will be exactly the required size. About $\frac{1}{10}$-inch to the foot is usually allowed for this. The castings are made in a mixture of sand and loam, which is held in place by two metal **flasks** resembling boxes with neither bottoms nor lids. The bottom flask is placed upon a

board or other flat surface, and filled with sand and loam rammed tightly into place. The pattern is then pressed into the sand, leaving about one half of it projecting above the surface of the sand, which is then smoothed over and made flush with the top of the flask. The whole is then sprinkled with a little fine brickdust. The top flask is now fitted to the bottom one by means of small bolts or pins, or both are chalked so that after removal they may be replaced in exactly the same positions. The sand is now rammed tightly into the second flask, and when this is full two or more holes are pierced to receive the liquid metal and to allow the air and gas to escape. Those to receive the metal are usually made wider at the top than at the bottom to facilitate the flow. The top flask is gently tapped to enable it to be drawn off the pattern more easily, and it is then removed with the sand still in it and laid carefully upon a board. The pattern is tapped in a similar way to slightly loosen it, and is then gradually withdrawn. It will be found that one half of the impression of the pattern has been left in each mould. Any slight defects are delicately touched up with small tools made in various shapes to fit corners, curves, etc., and the mould is then lightly coated over with **graphite** or black-lead to make the outside of the casting as smooth as possible. The top flask is replaced in exactly the same position as before, and the moulds allowed to dry. If any moisture remains in the mould when the metal is poured in, an explosion and accident are almost sure to be the result.

When the moulds are ready, the metal is tapped from the cupola into a vessel called a **ladle,** which, if large, is conveyed to the mould by a crane, but, if small, is carried by the moulder by means of a handle, and the liquid metal is poured through the prepared holes into the mould. When the metal reaches the top of the hole, the mould is full; it is then left to cool. When cold the sand is broken away from the metal, which will be found to be an exact representation of the pattern. The small **stick** or rod of metal which reached from the outside of the hole to the mould, and which is called a **runner,** is broken off with a hammer, and any roughness, etc., filed off, and the surface made smooth.

Sometimes a hole has to be left through a casting, as in the case of the ball weight on the screw press. To do this the flasks are filled with sand in the manner previously described, and a piece of sandstone, or iron plastered round with loam, is blackleaded. The piece of sandstone or iron is called a **core**. It is of the shape and size of the hole, and is inserted in the position required, and left there while the metal is poured into the mould. When cold this is easily withdrawn.

When brass castings are required the metal is melted in crucibles and poured direct into the moulds, the remainder of the process being similar to that for casting iron.



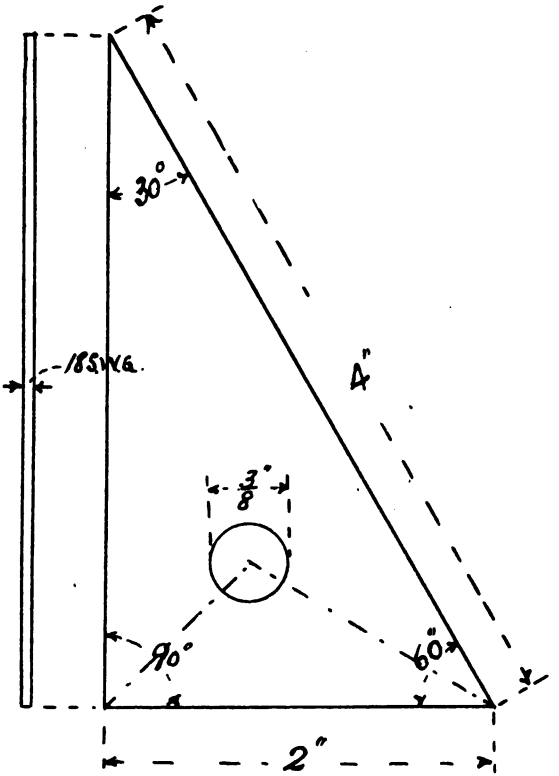
No. 1. Blade of Hoe (*see* No. 16).

Comprising:—**Simple filing, Marking out and Cutting** of 18 S.W.G. Mild Steel.

Tools required:—

Vice.
Flat File.
Scriber.
Straight-Edge.
Engineer's Square.
Shears.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



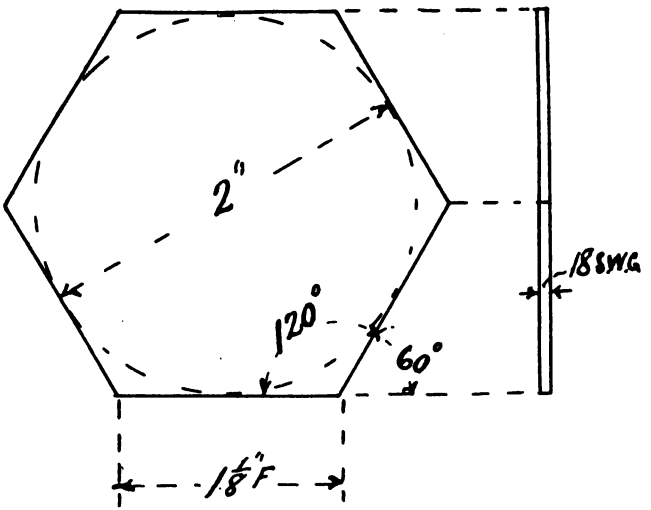
No. 2. SET SQUARE 60°.

Comprising:—Simple filing, Marking out and Cutting of 18 S.W.G. Mild Steel.

Tools required :—

Vice.
Flat File.
Scriber.
Straight-Edge.
Engineer's Square.
Wing Compasses.
Centre Punch.
Hammer.
Shears or **Chisel.**

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



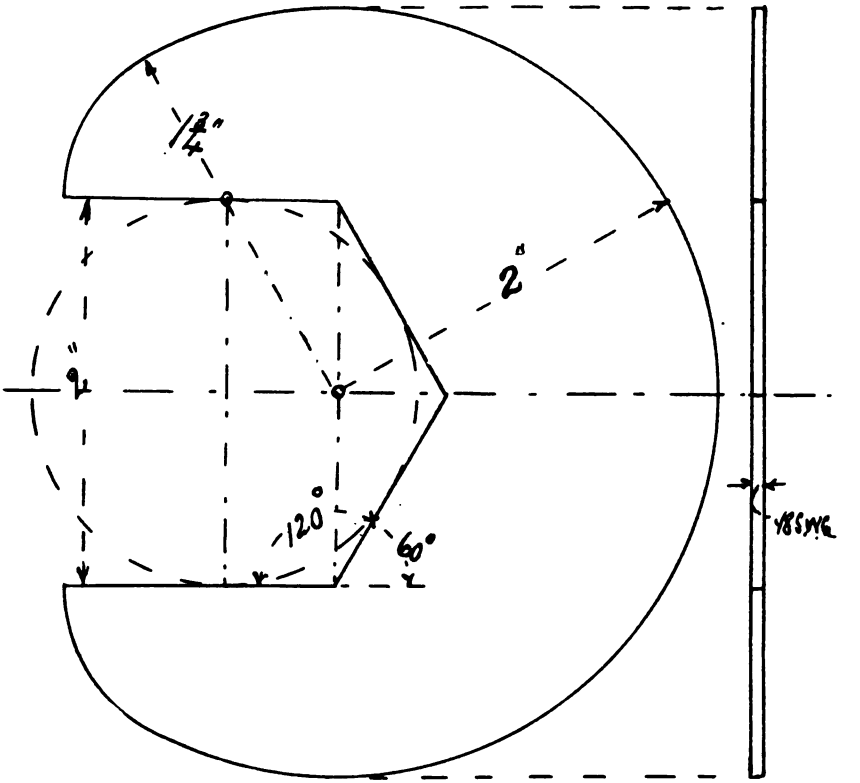
No. 3. HEXAGON (GAUGE FOR 120° ANGLE).

Comprising:—Simple filing, Marking out and Cutting of 18 S.W.G. Mild Steel.

Tools required:—

Vice.	Hammer.
Flat File.	**Scribing Block.**
Scriber.	**Surface Plate.**
Straight-Edge.	**Set Square 60°.**
Wing Compasses.	**Outside Callipers.**
Centre Punch.	Shears or Chisel.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



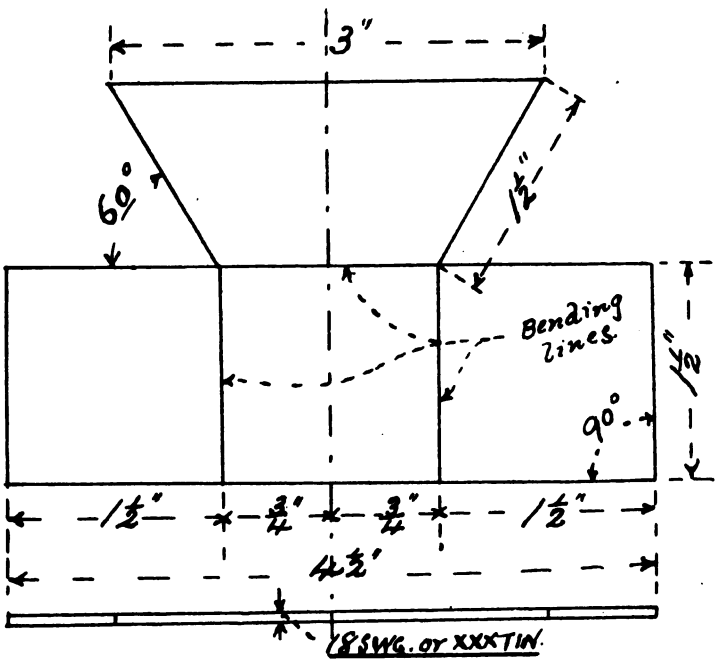
No. 4. SPANNER HEAD (GAUGE FOR HEXAGONAL NUTS).

Comprising:—**Filing curves**, Marking out, Cutting and **Punching** of 18 S.W.G. Mild Steel.

Tools required:—

Vice.
Flat File.
Triangular File.
Scriber.
Straight-Edge.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Surface Plate.
Set Square 60°.
Inside Callipers.
Shears or Chisel.
Screw Press.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 5*a*. RIVET OR CHALK HOLDER (FRONT).

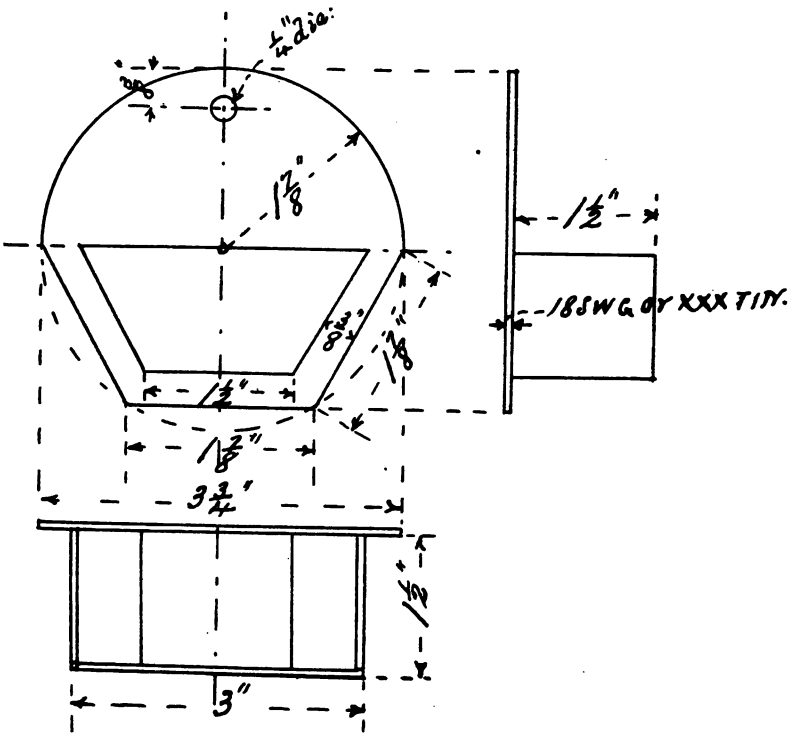
Comprising:—Marking out, Cutting, **Bending and Soldering of xxx tin.**

Tools required:—

Vice.	**Mallet.**
Scriber.	**Tinman's Snips.**
Straight-Edge.	**Soldering Bit.**
Engineer's Square.	**Solder.**
Scribing Block.	**Flux.**
Surface Plate.	Wing Compasses.

Set Square 60°.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 5*b*. RIVET OR CHALK HOLDER (COMPLETE).

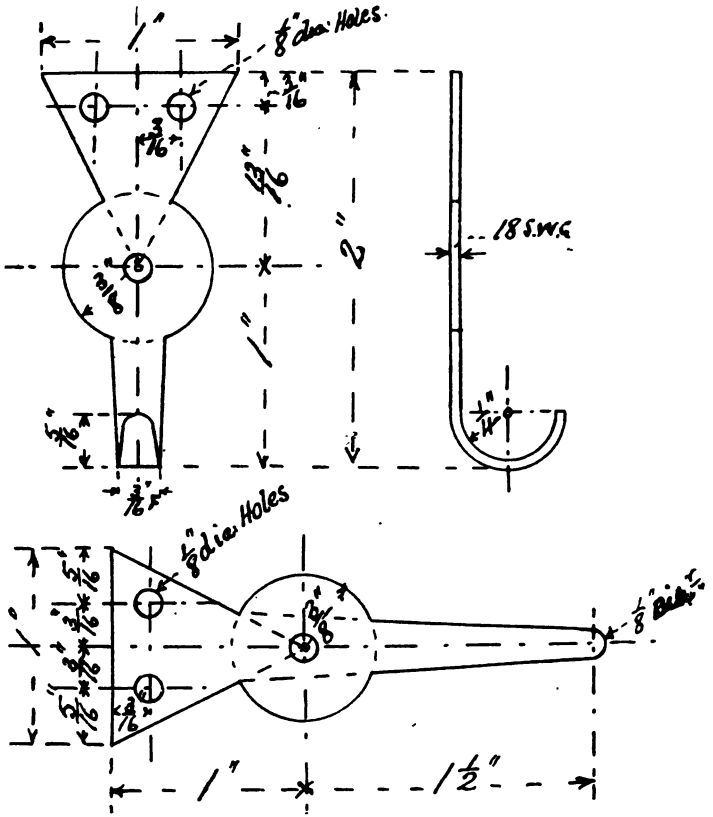
Comprising:—Marking out, Cutting, Soldering and **Drilling** of xxx tin.

Tools required:—

Scriber.
Straight-Edge.
Wing Compasses.
Centre Punch.
Set Square 60°.
Mallet.
Tinman's Snips.
Soldering Bit.
Solder.
Flux.

Drilling Machine.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 6. PICTURE HOOK (FOR NAILING OR SCREWING).

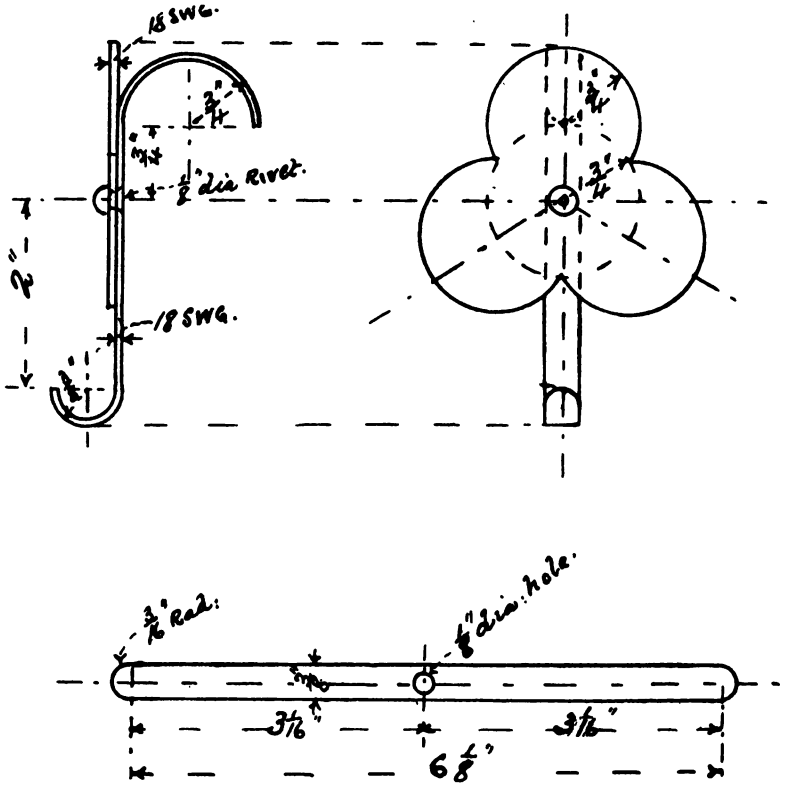
Comprising:—Filing, Drilling, Bending, Marking out and cutting of 18 S.W.G. Mild Steel.

Tools required:—

Vice.	Centre Punch.
Flat File.	Hammer.
Triangular File.	Scribing Block.
Scriber.	Surface Plate.
Straight-Edge.	Shears or Chisel.
Engineer's Square.	Drilling Machine.
Wing Compasses.	**Round Nosed Pliers** or a

Piece of ½-inch round iron.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 7. PICTURE HOOK (FOR HANGING UPON A MOULDING).

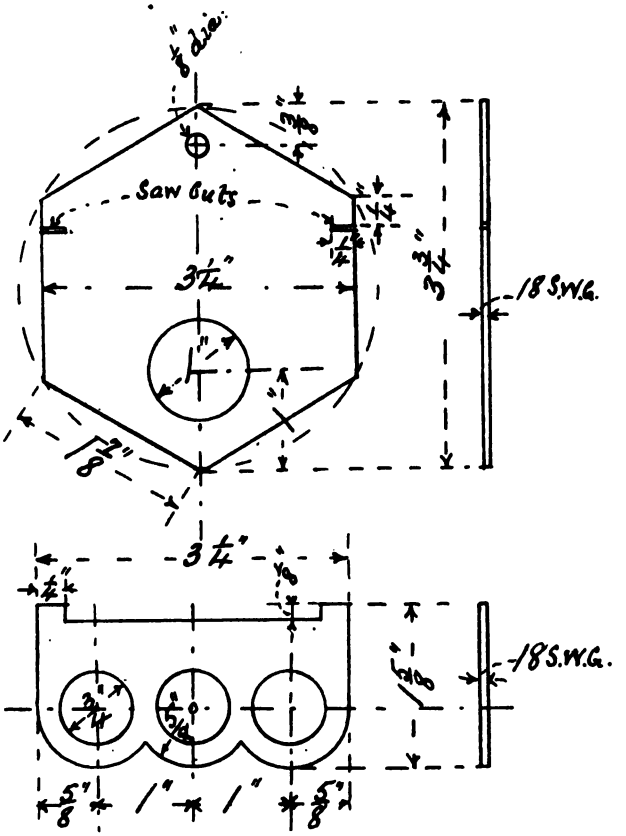
Comprising:—Filing, Marking out, Cutting, Drilling, Bending and **Riveting** of 18 S.W.G. Mild Steel.

Tools required:—

Vice.	Centre Punch.
Flat File.	Hammer.
Triangular File.	Drilling Machine.
Scriber.	Shears or Chisel.
Straight-Edge.	Round Nosed Pliers, or
Wing Compasses.	Piece of ½-inch round Iron.

Rivet.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



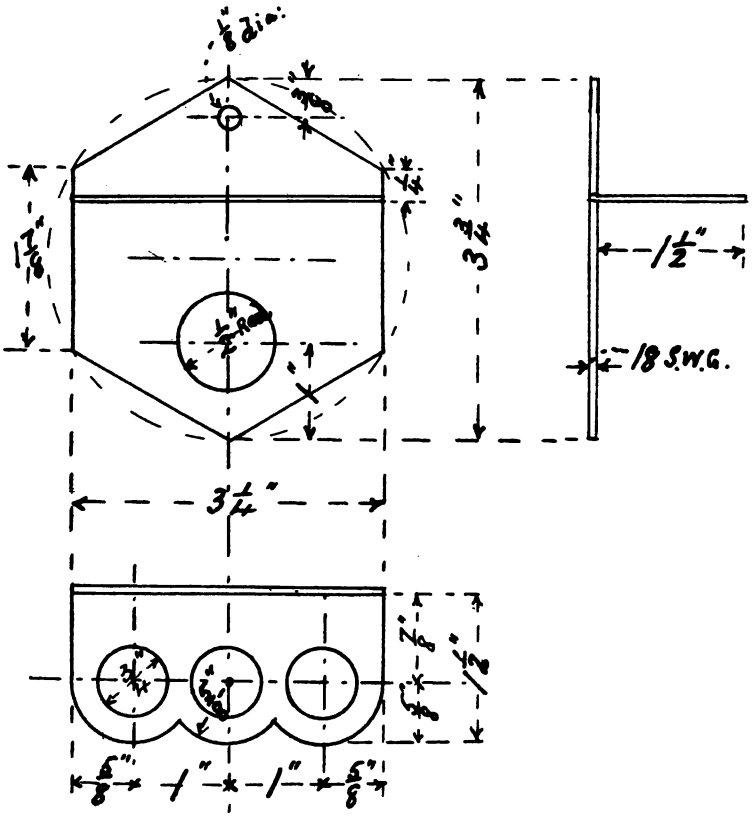
No. 8*a*. and *b*. RACK FOR 3 SMALL FILES.

Comprising:—Filing, Marking out, Riveting, **Sawing**, Cutting, Punching and Drilling of 18 S.W.G. Mild Steel.

Tools required:—

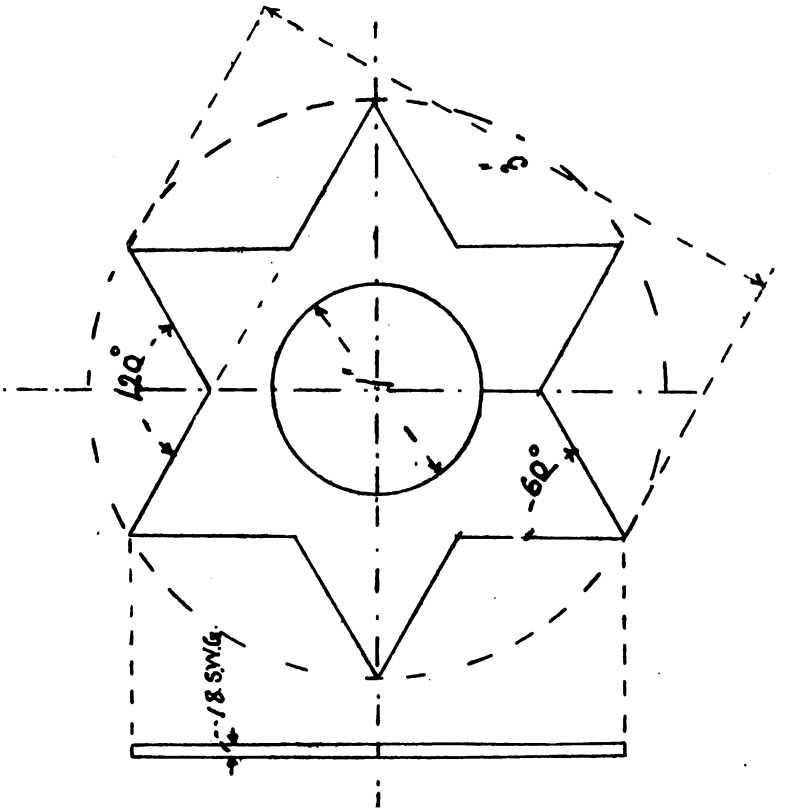
Vice.
Flat File.
Half-Round File.
Scriber.
Straight-Edge.
Engineer's Square.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Surface Plate.
Shears or Chisel.
Hacksaw.
Screw Press.
Drilling Machine.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 8*b*. RACK FOR 3 SMALL FILES (COMPLETE).

See No. 8*a*. and *b*.



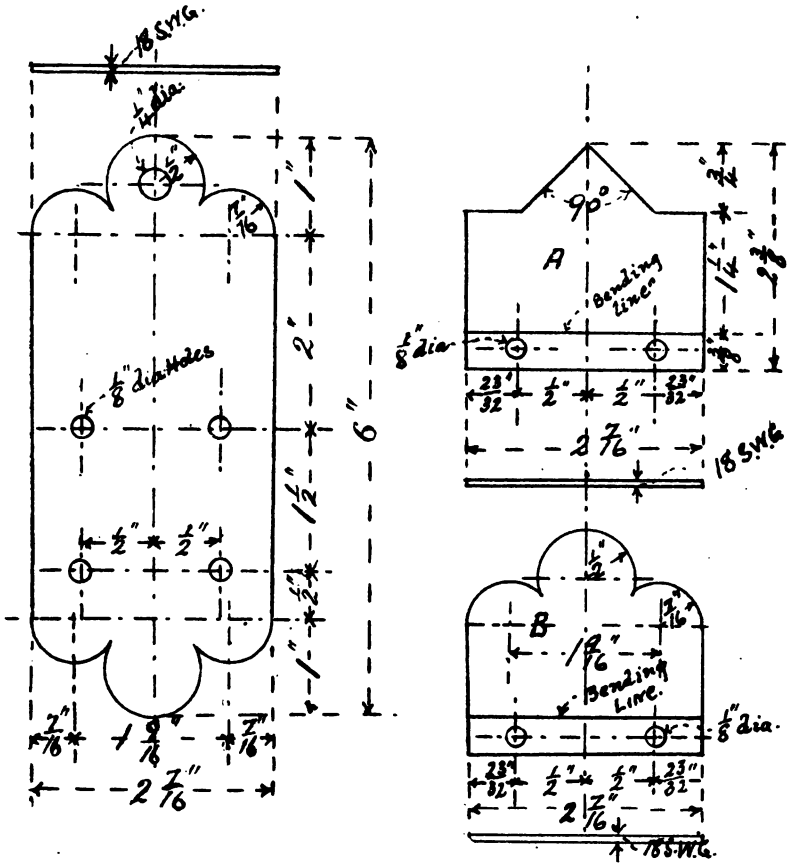
No. 9. SIMPLE INLAYING AND GAUGE FOR HEXAGON.

Comprising:—Filing, Marking out, Cutting and Punching of 18 S.W.G. Mild Steel, and **Inlaying Brass** Circle.

Tools required:—

Vice.
Half-Round File.
Flat File.
Scriber.
Straight-Edge.
Wing Compasses.
Centre Punch.
Hammer.
Shears or Chisel.
Screw Press.
Hexagon (for testing 120° angle).

New tools and principles, in heavy type, demonstrated as the lesson proceeds.

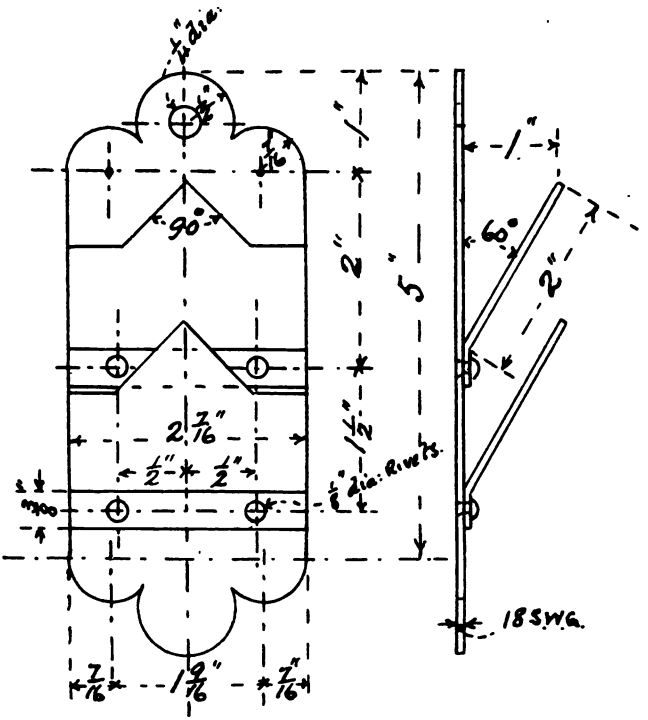


No. 10*a*. and *b*. LETTER RACK.

Comprising:—Filing, Marking out, Cutting, Riveting, Drilling and Bending of 18 S.W.G. Mild Steel.

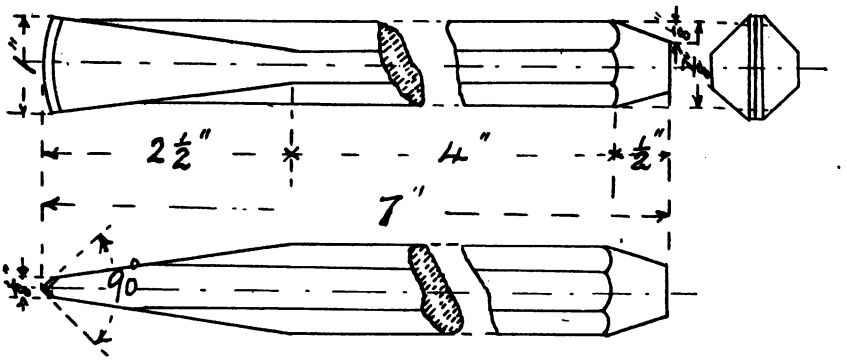
Tools required:—

Vice.
Flat File.
Triangular File.
Scriber.
Straight-Edge.
Engineer's Square.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Surface Plate.
Shears or Chisel.
Drilling Machine.
Rivets.



No. 10*b*. Letter Rack (Complete).

See No. 10*a*. and *b*.



No. 11. COLD FLAT CHISEL.

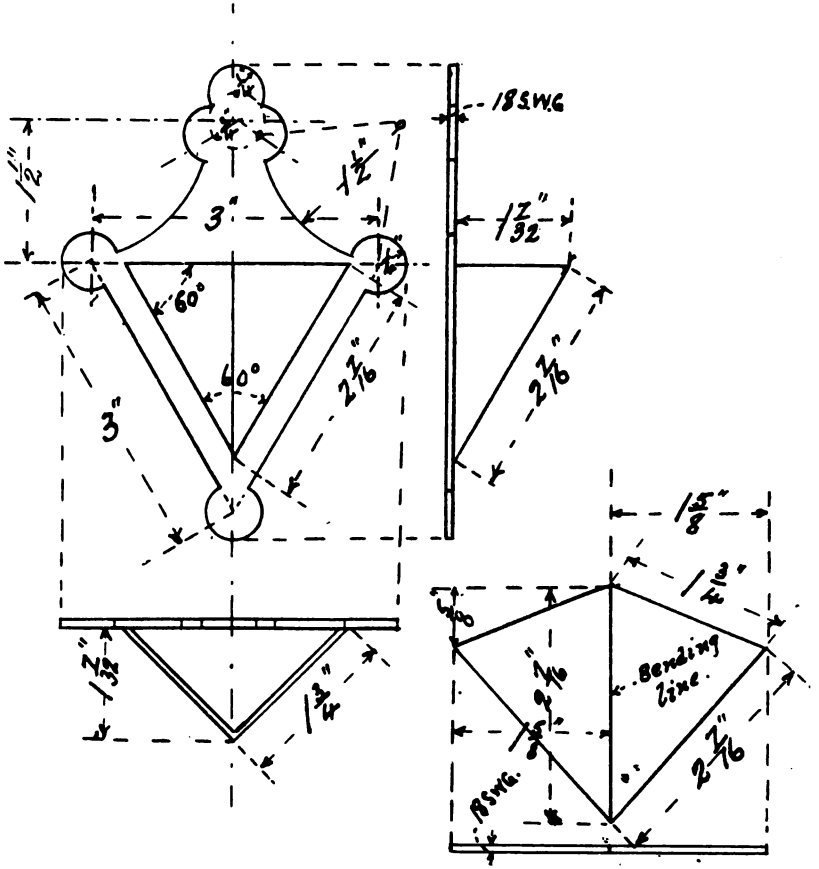
Comprising:—**Forging, Grinding, Hardening, Tempering,** and **Annealing** of **Octagonal Tool Steel.**

Tools required:—

Forge.	Hammer (**Sledge**).
Water Trough.	**Flatter.**
Anvil.	**Grindstone.**
Tongs.	**Hot Set.**

New tools and principles, in heavy type, demonstrated as the lesson proceeds.

N.B.—This exercise to be worked conjointly with No. 12.—*See* Introduction.

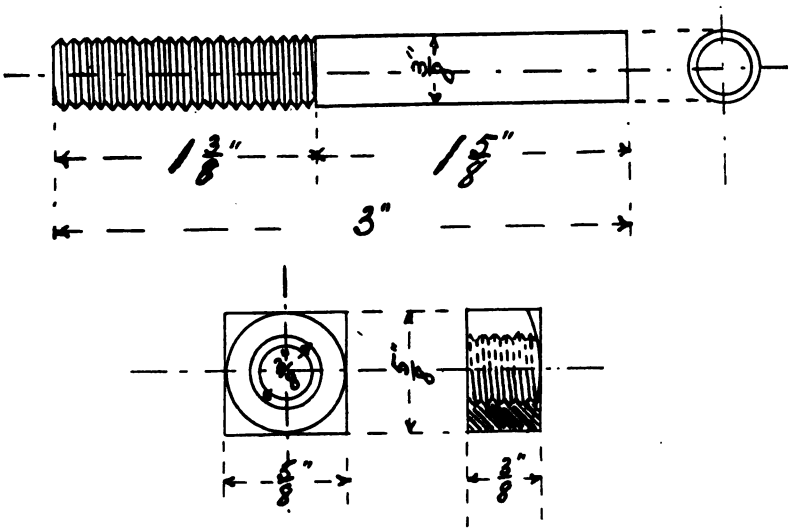


No. 12. MATCH HOLDER.

Comprising:—Filing, Marking out, Cutting, Bending, Soldering, Drilling of 18 S.W.G. Mild Steel.

Tools required:—

Vice.	Hammer.
Flat File.	Scribing Block.
Half-Round File.	Surface Plate.
Scriber.	Shears or Chisel.
Engineer's Square.	Drilling Machine.
Straight-Edge.	Soldering Bit.
Wing Compasses.	Solder.
Centre Punch.	Flux.



No. 13. NUT AND BOLT.

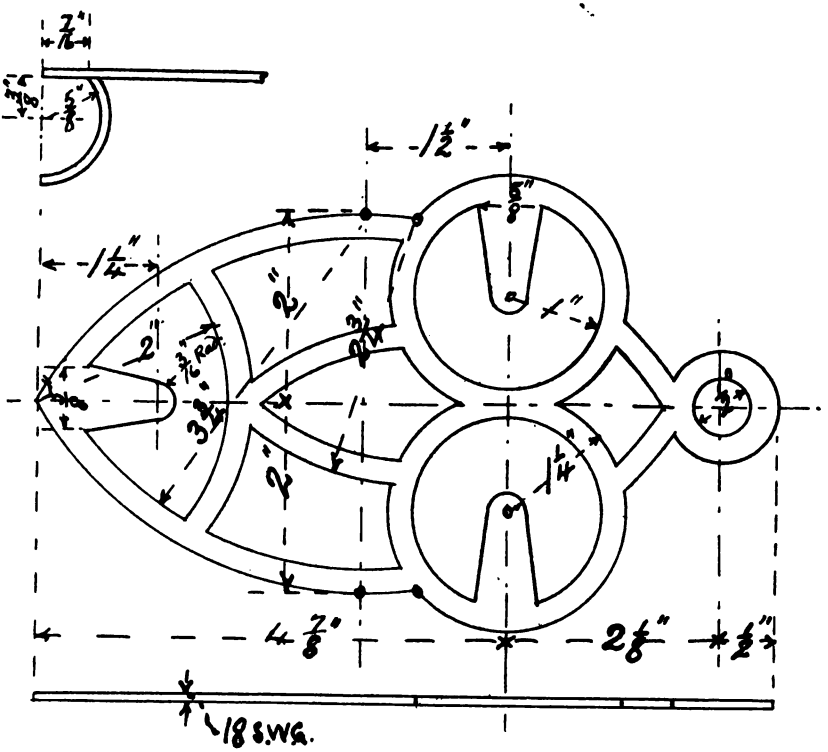
Comprising:—Filing, Sawing, **Tapping, Screwing,** Drilling, Marking out of Wrought Iron.

Tools required:—

Vice.	Wing Compasses.
Flat File.	Centre Punch.
Hacksaw.	Hammer.
Scriber.	**Stocks and Dies.**
Straight-Edge.	**Taps and Wrenches.**
Engineer's Square.	Drilling Machine.
Surface Plate.	Scribing Block.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.

N.B.—This exercise to be worked conjointly with No. 14.—*See* Introduction.



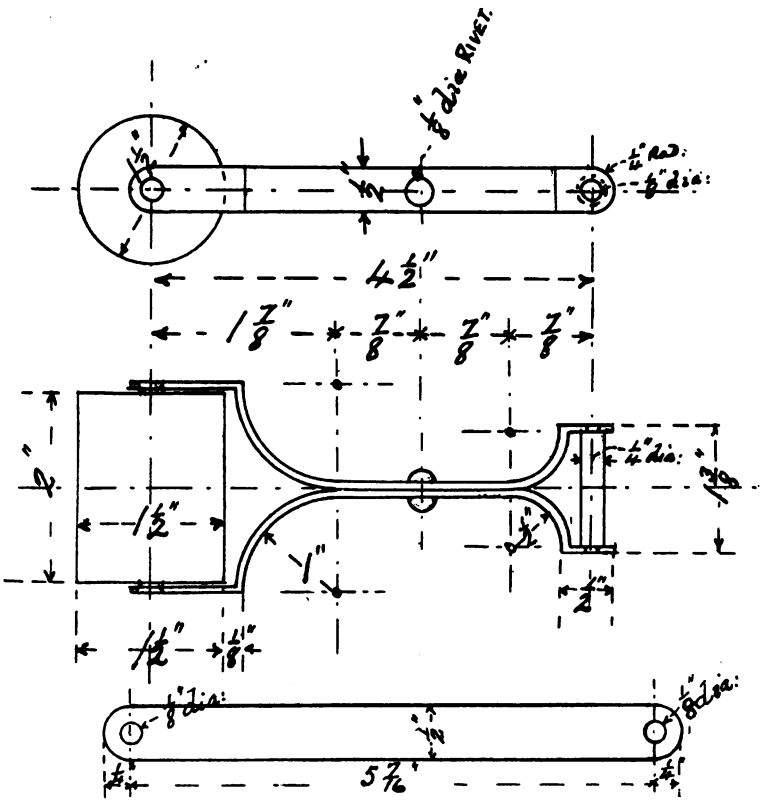
No. 14. IRON STAND.

Comprising:—More difficult Filing, Punching, Marking out, Cutting and Bending of 18 S.W.G. Mild Steel.

Tools required:—

Vice.	Hammer.
Flat File.	Scribing Block.
Half-Round File.	Surface Plate.
Scriber.	Shears or Chisel.
Straight-Edge.	Screw Press.
Engineer's Square.	Outside Callipers.
Wing Compasses.	Round-Nosed Pliers, or
Centre Punch.	Piece of $\frac{5}{8}$ Round Iron.

Lesson on the Manufacture of Iron, *continued.*



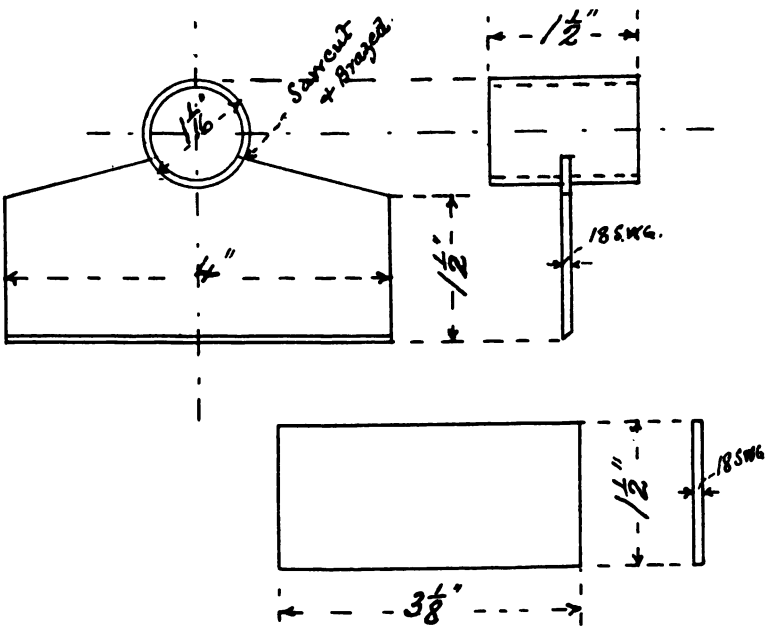
No. 15. ROLLER.

Comprising:—Filing, Marking out, Cutting, Bending, Riveting, Drilling, **Centreing and Turning** of Mild Steel.

Tools required:—

Vice.
Flat File.
Scriber.
Straight-Edge.
Engineer's Square.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Surface Plate.
Vee Block.
Shears or Chisel.
Drilling Machine.
Round-Nosed Pliers.
Lathe { Roughing Tool. Finishing ,, Side-Facing ,,

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 16. HOE.

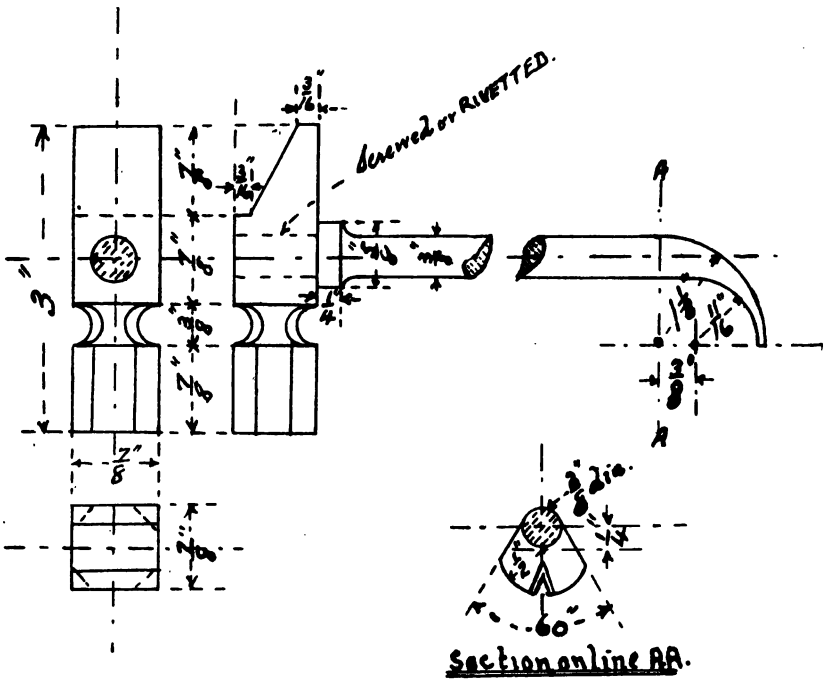
Comprising:—Filing, Marking out, Cutting, Bevelling, Sawing, Bending and **Brazing** of 18 S.W.G. Mild Steel.

Tools required:—

Vice.	Surface plate.
Flat File.	Shears or Chisel.
Half-Round File.	**Blow Pipe or Forge.**
Scriber	Piece of 1-inch Round Iron.
Straight-Edge.	**Spelter and Borax.**
Engineer's Square.	Outside Callipers.
Wing Compasses.	Inside ,,
Centre Punch.	Hammer.

Scribing Block.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



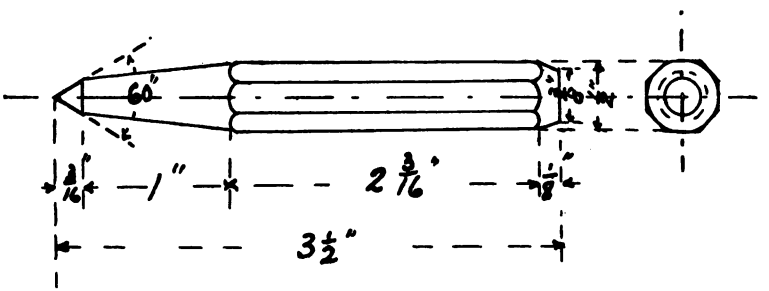
No. 17. HAMMER.

Comprising:—More difficult Filing, Marking out, Drilling, Tapping, Screwing or Riveting, Forging, Centreing and Turning of Mild Steel or Wrought Iron.

Tools required:—

Vice.
Flat File.
Round File.
Scriber.
Straight-Edge.
Engineer's Square.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Vee Block.
Surface Plate.
Drilling Machine.
Taps and Wrenches.
Stocks and Dies.
Set Square 45°.
Lathe { Roughing Tool. Finishing ,, Side-Facing Tool.
Forge { Anvil. Tongs. Hot Set.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 18. CENTRE PUNCH.

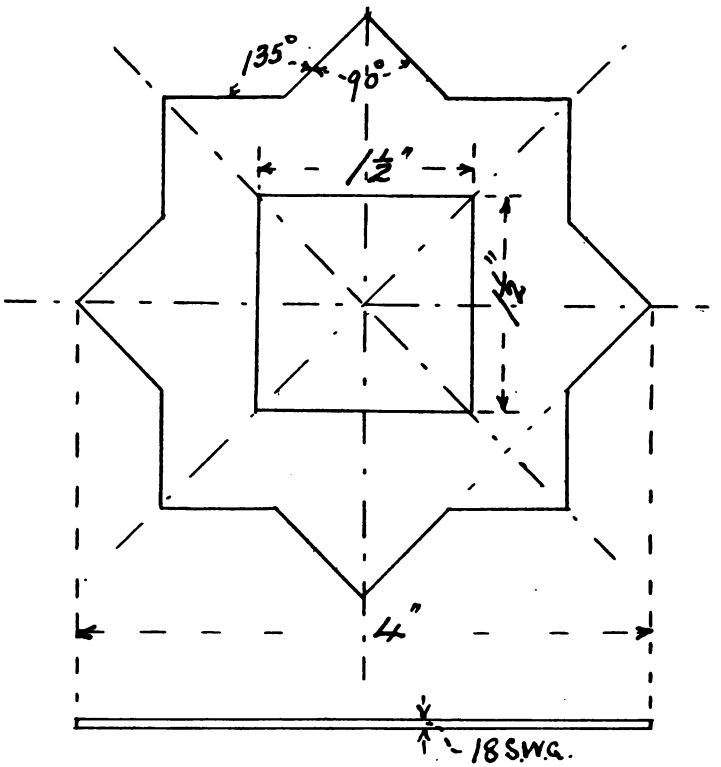
Comprising:—Forging, Grinding, Hardening, Tempering and Annealing of Octagonal Tool Steel.

Tools required:—

Tongs.
Anvil.
Water Trough.
Forge.
Grindstone.
Gauge for 60° angle.
Flatter.
Hot Set.
Hammer.

Lesson on the Puddling Furnace and Manufacture of Wrought Iron.

N.B.—This exercise to be worked conjointly with No. 19.—*See* Introduction.



No. 19. MORE DIFFICULT INLAYING.

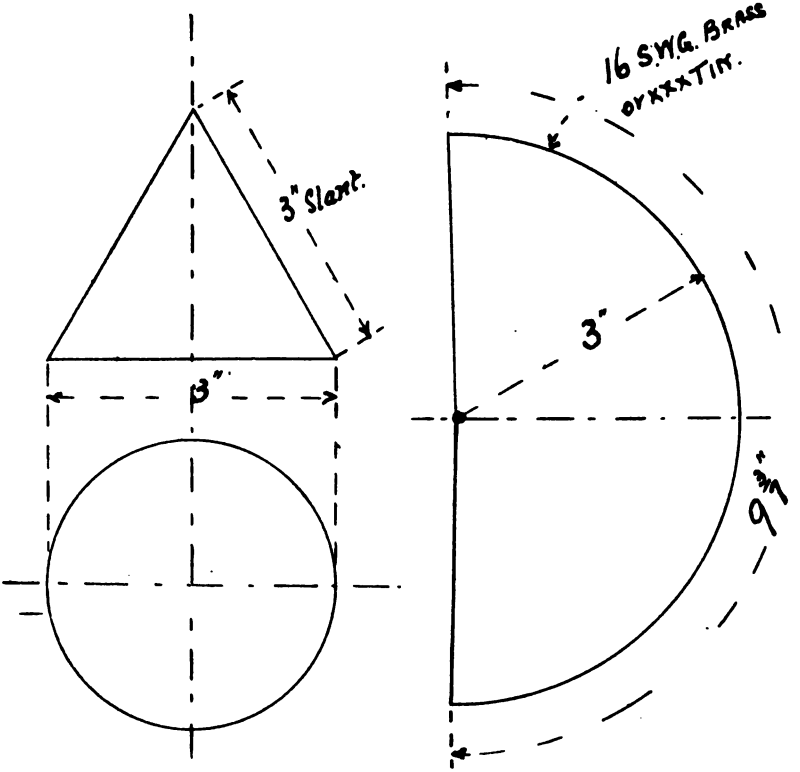
Comprising:—Filing, Marking out, Cutting in 18 S.W.G. Steel and Inlaying Brass Square.

Tools required:—

Vice.	Centre Punch.
Flat File.	Hammer.
Triangular File.	Scribing Block.
Scriber.	Surface Plate.
Straight-Edge.	Shears or Chisel.
Engineer's Square.	Set Square 45°.

Wing Compasses.

Lesson on the properties of Brass, Copper, Tin, Lead and Zinc.



No. 20. CONE IN TIN.

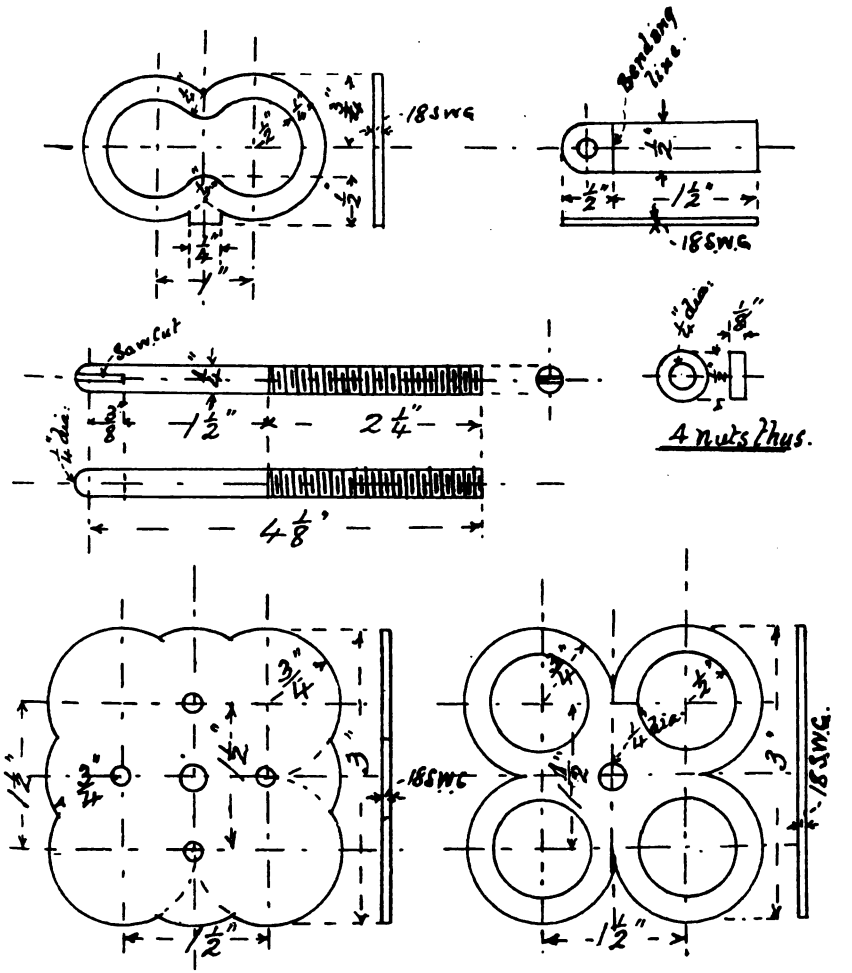
Comprising:—Cutting, Marking out, Bending and Soldering of xxx tin.

Tools required:—

Vice.	Wing Compasses.
Tinman's Snips.	Mallet.
Scriber.	**Taper Stake or Beck Iron.**
Straight-Edge.	Soldering Bit.

Solder and Flux.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



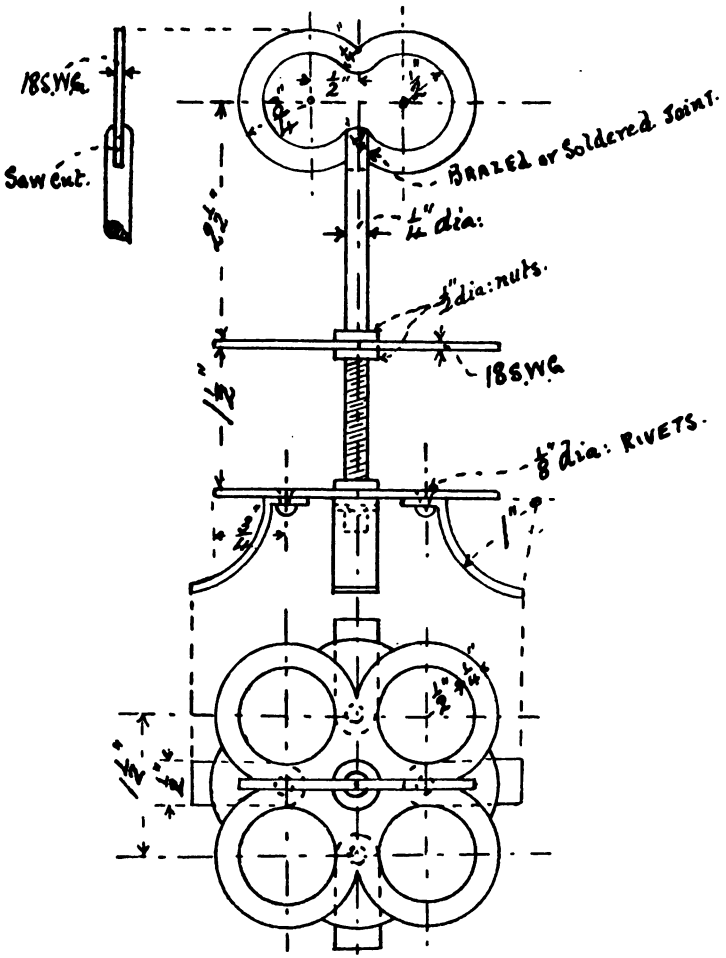
No. 21*a*. and *b*. CRUET.

Comprising:—Filing, Marking out, Cutting, Sawing, Screwing, Tapping, Drilling, Riveting, Bending, Punching, Brazing in Mild Steel and Wrought Iron.

Tools required:—

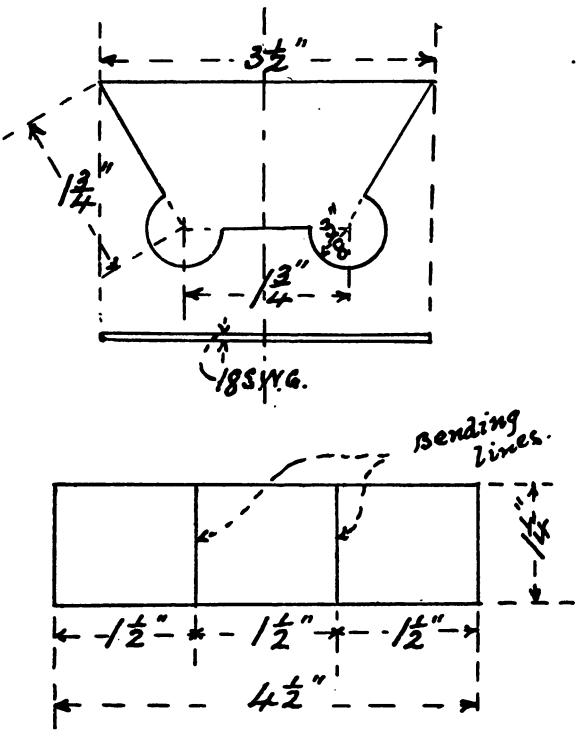
Vice.	Hammer.	Stocks and Dies.
Flat File.	Scribing Block.	Hacksaw.
Half-Round File.	Rivets.	Blow Pipe or Forge.
Scriber.	Surface Plate.	Drilling Machine.
Straight-Edge.	Shears or Chisel.	Round-Nosed Pliers or
Engineer's Square.	Screw Press.	Piece 1-inch Round Iron.
Wing Compasses.	Taps and Wrenches.	Borax and Spelter.
Centre Punch.		

Lesson on the Manufacture of Mild Steel.



No. 21*b*. CRUET (COMPLETE).

See No. 21*a*. and *b*.



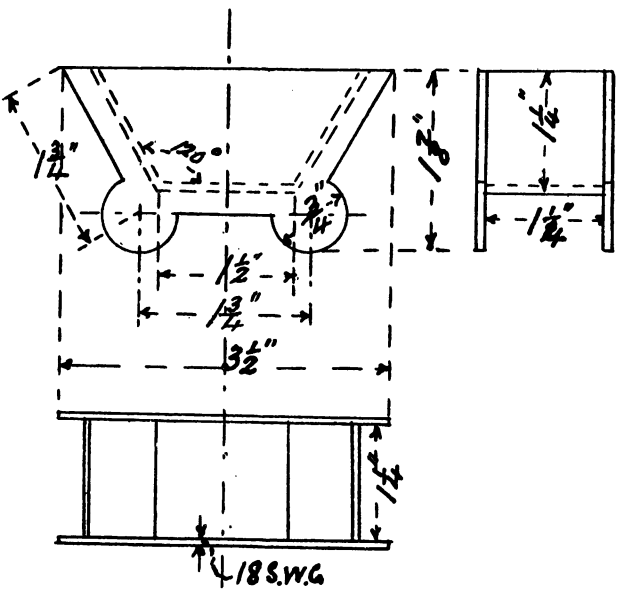
No. 22*a*. and *b*. TRUCK.

Comprising:—Filing, Marking out, Cutting, Bending, and more difficult Soldering of 18 S.W.G. Mild Steel.

Tools required:—

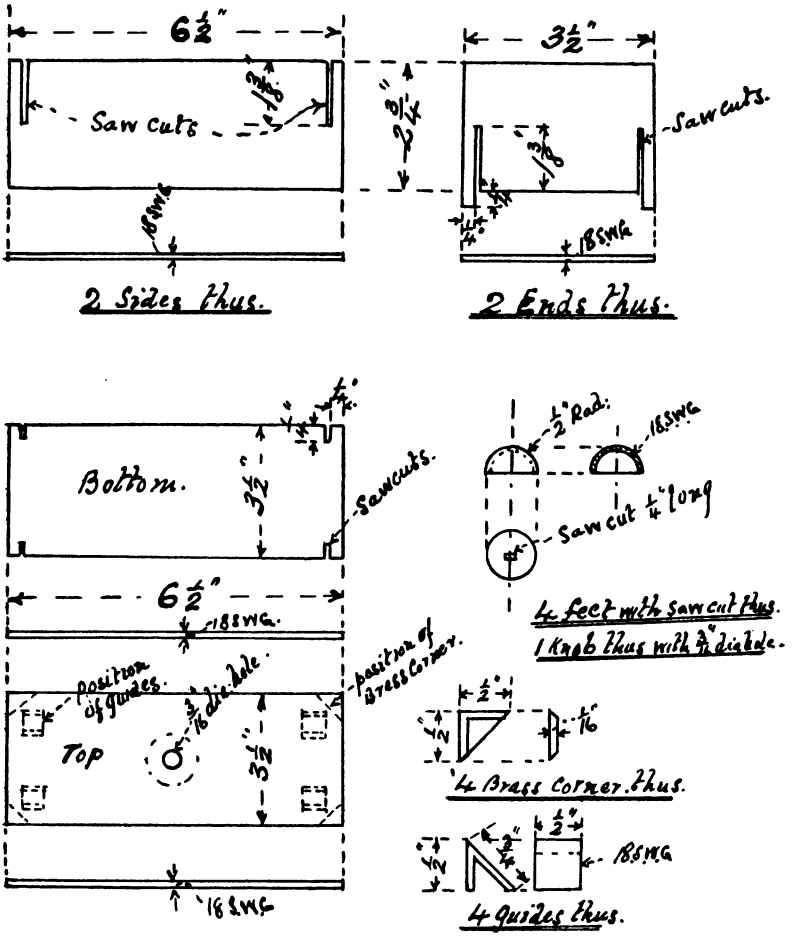
Vice.
Flat File.
Triangular File.
Scriber.
Straight-Edge.
Engineer's Square.
Soldering Bit.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Surface Plate.
Shears or Chisel.
Solder and Flux.

Lesson on the Manufacture of Tool Steel.



No. 22*b*. TRUCK (COMPLETE).

See No. 22*a*. and *b*.



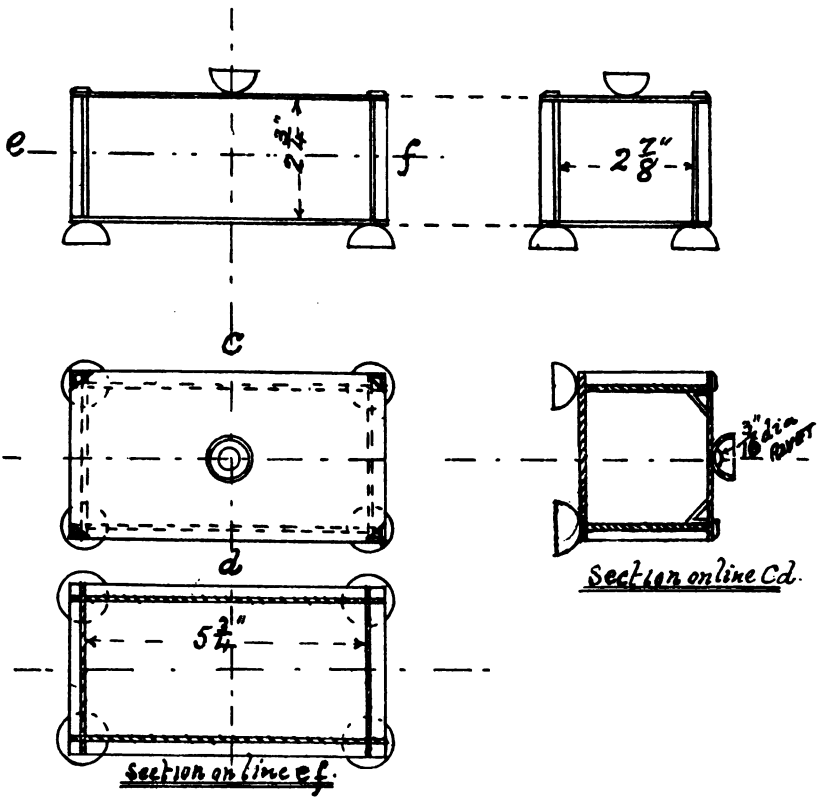
No. 23*a*. and *b*. Box.

Comprising:—Filing, Marking out, Cutting, Sawing, Drilling, Riveting, Soldering and Bending of 18 S.W.G. Mild Steel and Brass.

Tools required:—

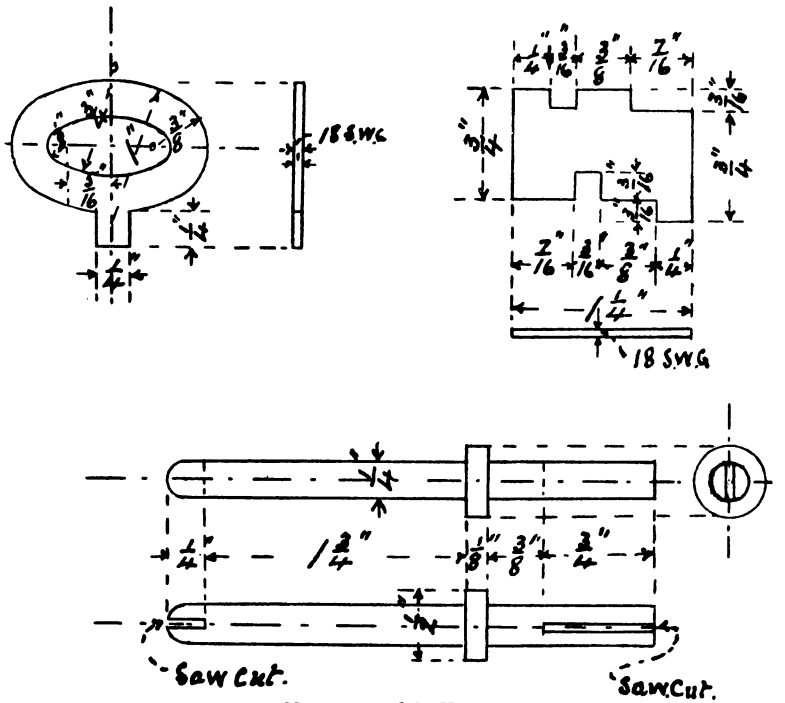
Vice.	Wing Compasses.	Hacksaw.
Flat File.	Centre Punch.	Screw Press.
Triangular File.	Hammer.	Drilling Machine.
Scriber.	Scribing Block.	Rivets.
Straight-Edge.	Surface Plate.	Soldering Bit.
Engineer's Square.	Shears or Chisel.	Solder and Flux.

Lesson on the Preservation of Metals.



No. 23*b*. Box (Complete).

See No. 23*a*. and *b*.



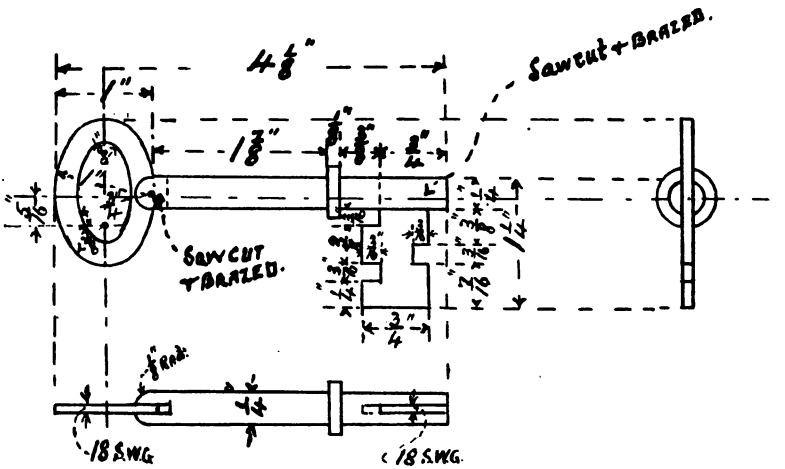
No. 24*a*. and *b*. KEY.

Comprising:—Filing, Marking out, Cutting, Sawing, Punching, or Drilling, Simple Turning and Brazing of Mild Steel.

Tools required:—

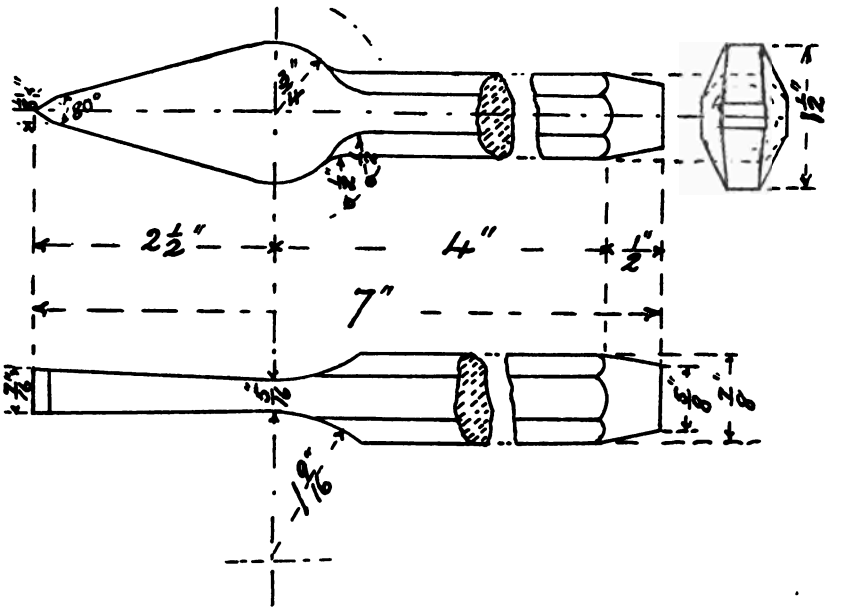
Vice.
Flat File.
Fish-Back File.
Square File.
Rat-tail File.
Triangular File.
Scriber.
Straight-Edge.
Engineer's Square.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Vee Block.
Surface Plate.
Shears or Chisel.
Screw Press or
Drilling Machine.
Blow Pipe or Forge.
Hacksaw.
Spelter and Borax.
Lathe { Roughing Tool. / Finishing ,, / Side-Facing Tool.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 24*b*. KEY (COMPLETE).

See No. 24*a*. and *b*.



No. 25. Cross-Cut Chisel.

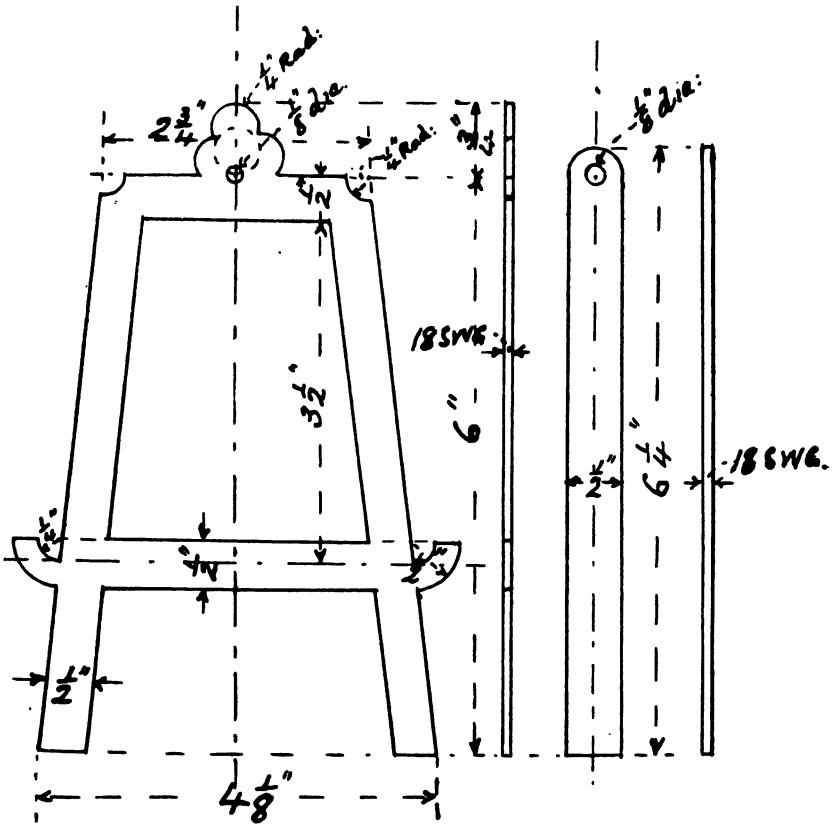
Comprising:—Forging, Grinding, Annealing, **Fullering**, Hardening and Tempering of Octagonal Tool Steel.

Tools required:—

Forge.	Hammer (Sledge).
Water Trough.	Flatter.
Anvil.	Hot Set.
Tongs.	**Top and Bottom Fullers.**

New tools and principles, in heavy type, demonstrated as the lesson proceeds.

N.B.—This exercise to be worked conjointly with No. 26.—*See* Introduction.



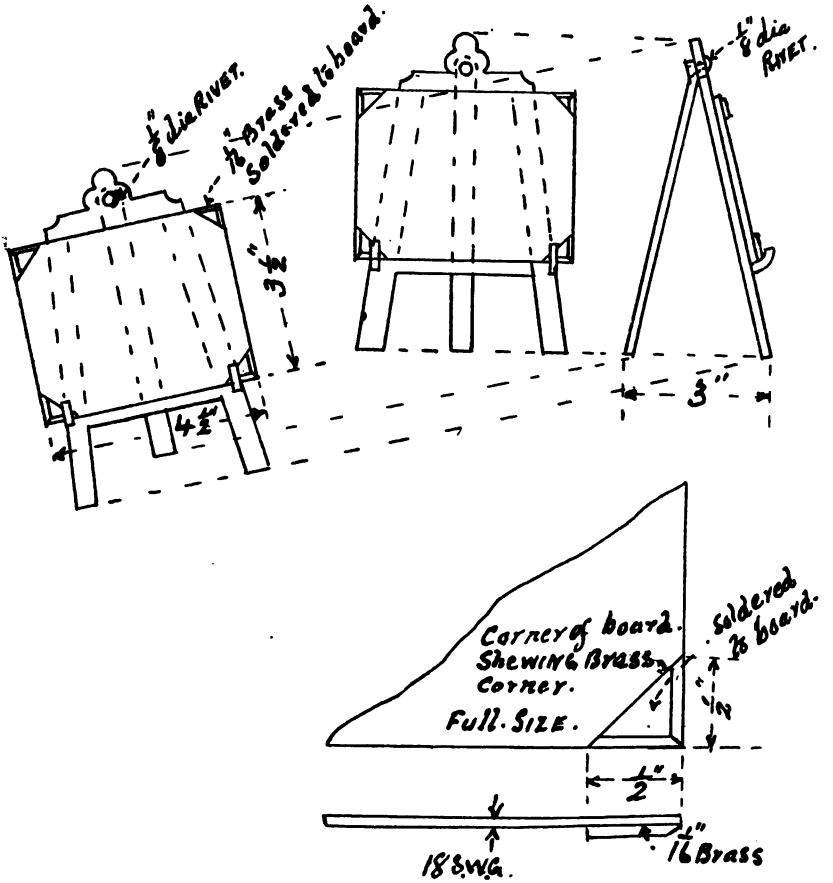
No. 26*a*. and *b*. BOARD AND EASEL.

Comprising:—Filing, Marking out, Cutting, Soldering, Riveting and Bending of 18 S.W.G. Mild Steel and Brass.

Tools required:—

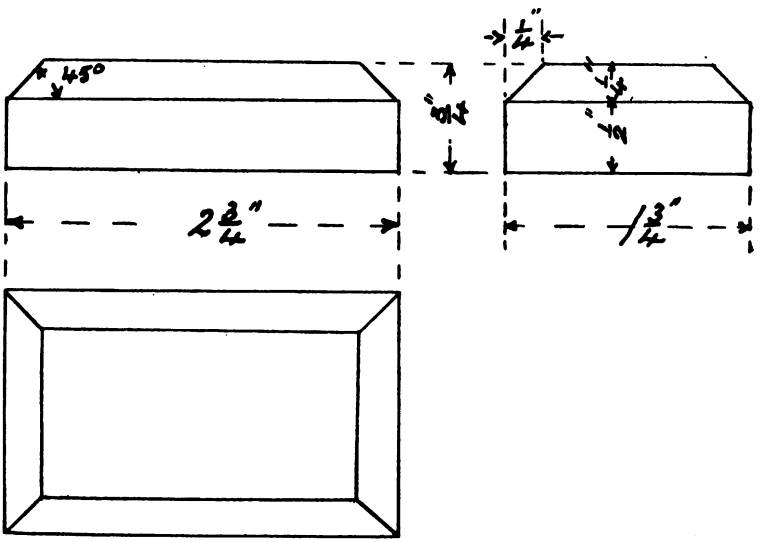
Vice.	Hammer.
Flat File.	Scribing Block.
Half-Round File.	Surface Plate.
Scriber.	Shears or Chisel.
Straight-Edge.	Screw Press.
Engineer's Square.	Drilling Machine.
Wing Compasses.	Soldering Bit.
Centre Punch.	Solder and Flux.
Rivet.	

Lesson on Moulding and Casting in Iron, etc.



No. 26*b*. Board and Easel (Complete).

See No. 26*a*. and *b*.



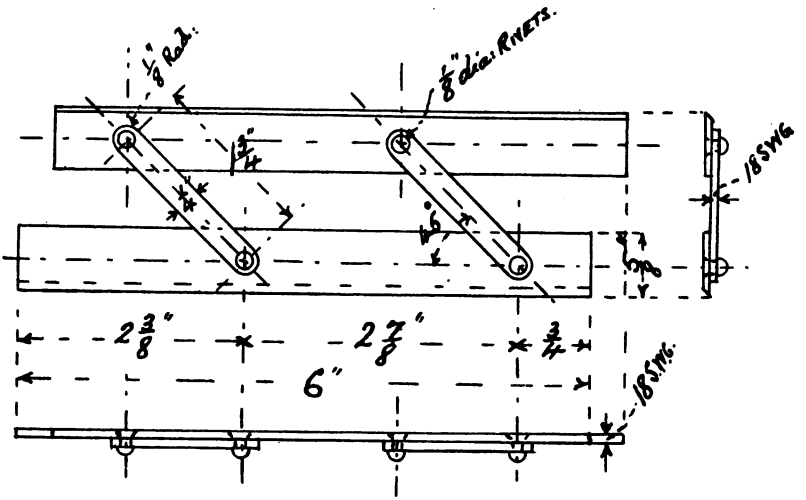
No. 27. PAPER WEIGHT.

Comprising:—Filing, Marking out, **Chipping** and **Bevelling of Cast Iron.**

Tools required:—

Vice.
Rough and Smooth Flat File.
Scriber.
Straight-Edge.
Engineer's Square.
Cross-Cut and Flat Chisels.
Scribing Block.
Surface Plate.
Hammer.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



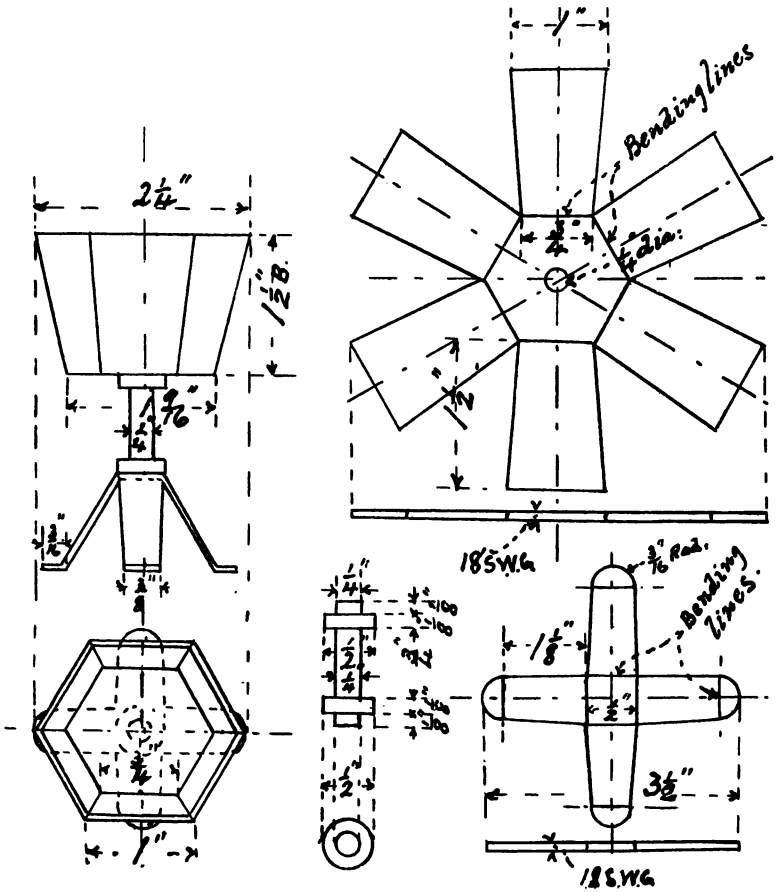
No. 28. PARALLEL RULE.

Comprising:—Filing, Marking out, Drilling, Cutting and Riveting of 18 S.W.G. Mild Steel.

Tools required:—

Vice.
Flat File.
Triangular File.
Scriber.
Straight-Edge.
Engineer's Square.
Wing Compasses.
Centre Punch.
Hammer.
Scribing Block.
Surface Plate.
Shears or Chisel.
Drilling Machine.
Rivets.
Outside Callipers.

Lesson on Welding.



No. 29. SMALL VASE.

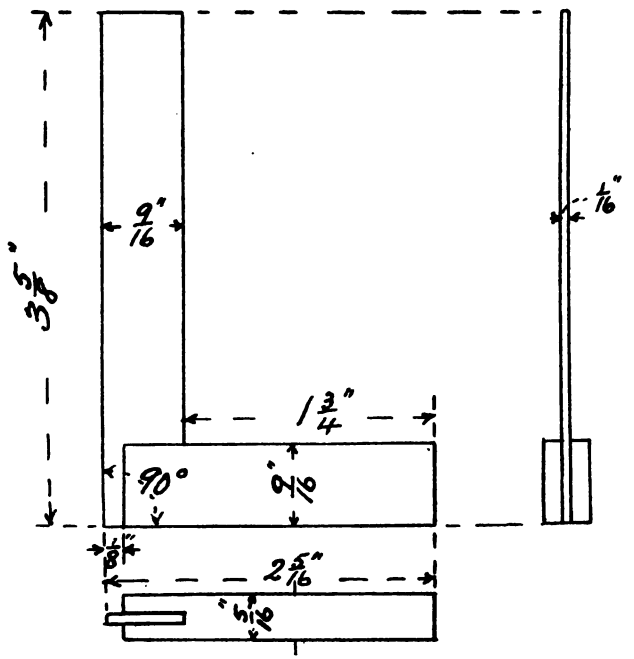
Comprising:—Filing, Marking out, Cutting, Bending, Drilling, Riveting and Turning of Mild Steel.

Tools required:—

Vice.	Wing Compasses.	Shears or Chisel.
Flat File.	Centre Punch.	Drilling Machine.
Triangular File.	Hammer.	Lathe { Roughing Tool.
Scriber.	Scribing Block.	Lathe { Finishing ,,
Straight-Edge.	Vee Block.	Lathe { Side-Facing Tool.
Engineer's Square.	Surface Plate.	

Piece of ¾-inch and ½-inch Square Iron.

Lesson on Bent Iron Work, Round and Square-Nosed Pliers.



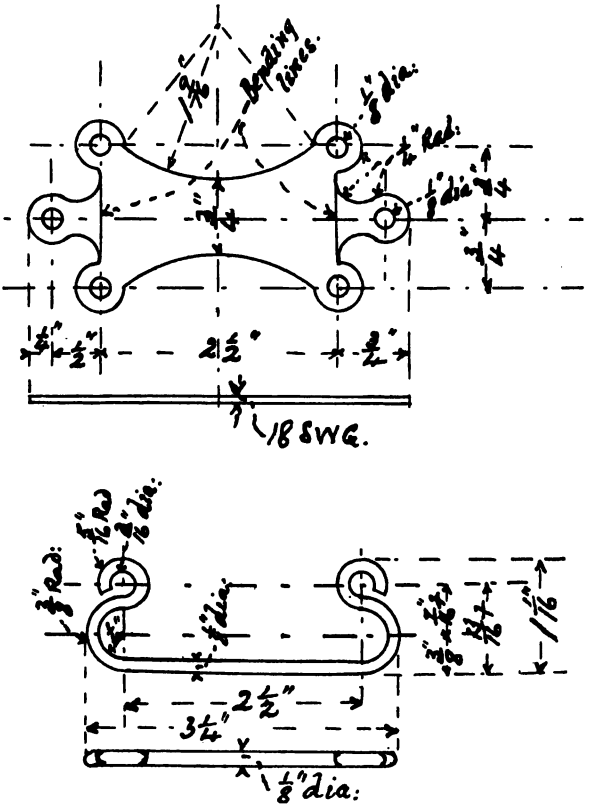
No. 30. ENGINEER'S SQUARE.

Comprising:—Filing, **Bending, Drawing down,** Marking out and Cutting of Steel.

Tools required:—

Vice.	Scribing Block.
Flat and Smooth Files.	Surface Plate.
Scriber.	Forge.
Straight-Edge.	Anvil.
Engineer's Square.	Tongs.
Outside Callipers.	Hammer (Sledge).
Hot set.	Flatter.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



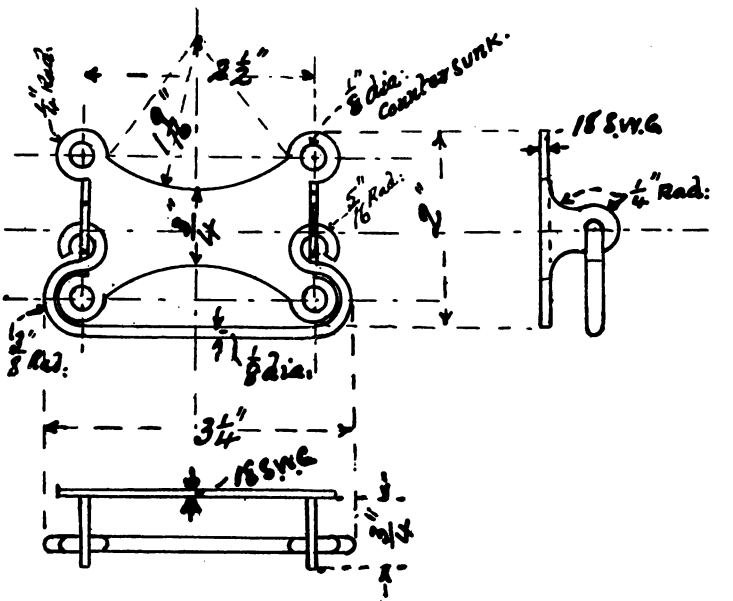
No. 31*a*. and *b*. DRAWER HANDLE.

Comprising:—Filing, Marking out, Cutting, Drilling and Bending of 18 S.W.G. Mild Steel.

Tools required:—

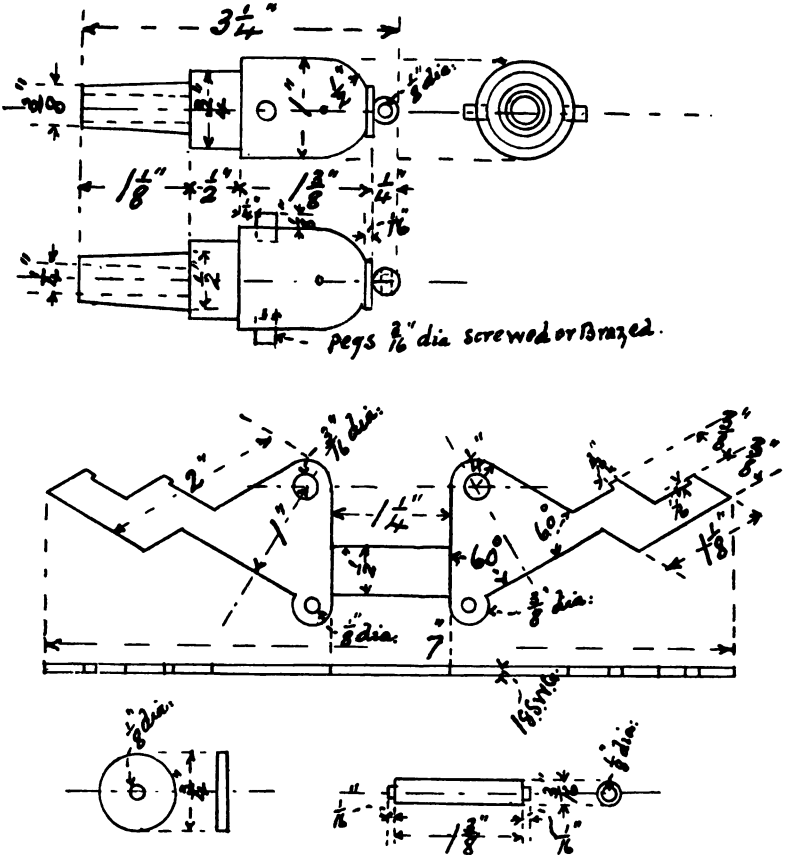
Vice.	Centre Punch.
Flat File.	Hammer.
Half-Round File.	Scribing Block.
Scriber.	Surface Plate.
Straight-Edge.	Shears or Chisel.
Engineer's Square.	Drilling Machine.
Wing Compasses.	Round-Nosed Pliers.

Lesson on Forging, Hardening and Tempering of Lathe Tools.



No. 31*b*. Drawer Handle (Complete).

See No. 31*a*. and *b*.



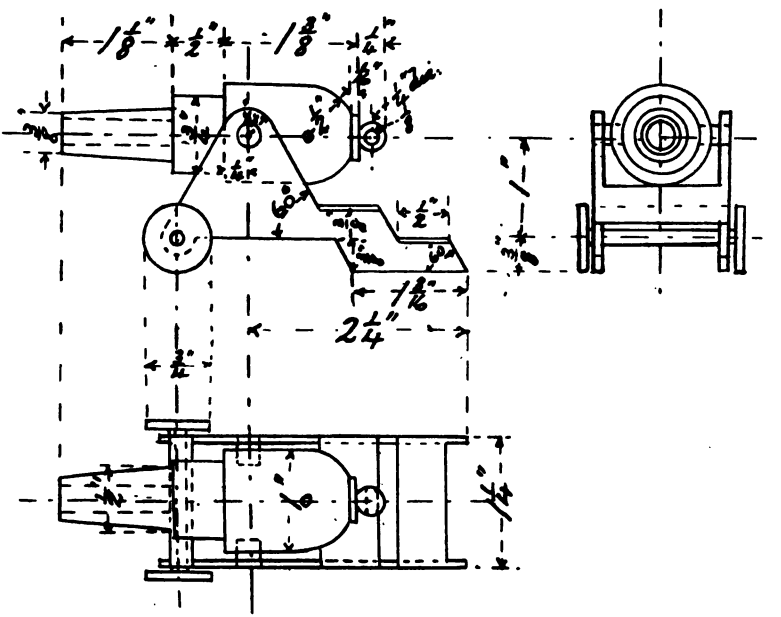
No. 32*a*. and *b*. SMALL CANNON.

Comprising:—Turning, **Chucking**, Centreing, Brazing, Drilling, Bending, Riveting, Filing, Marking out and Cutting of Mild Steel.

Tools required:—

Vice.	Centre Punch.	Shears or Chisel.
Flat File.	Blow Pipe or Forge.	Drilling Machine.
Triangular File.	Spelter and Borax.	Lathe { Roughing Tool.
Scriber.	Scribing Block.	Lathe { Finishing ,,
Straight-Edge.	Vee Block.	Lathe { Side Facing ,,
Engineer's Square.	Hammer.	Lathe { **Corner** ,,
Wing Compasses.	Surface Plate.	Lathe { **Chuck**.

New tools and principles, in heavy type, demonstrated as the lesson proceeds.



No. 32*b*. SMALL CANNON (COMPLETE).

See No. 32*a*. and *b*.

TOOLS AND MACHINES REQUIRED FOR TWENTY BOYS

TOOLS REQUIRED FOR EACH BOY

	£	s.	d.
Cast Steel Hammer, with shaft (engineer's pattern, 12 oz.)	0	1	6
Cold Chisel, Flat	0	1	0
Cold Chisel, Cross Cut	0	1	0
Scriber	0	0	4
Steel Straight-Edge, marked $\frac{1}{64}$, $\frac{1}{32}$, $\frac{1}{16}$, etc., 12 in. long	0	1	3
Engineer's Square (3 in.)	0	1	6
Outside Callipers (3½ in.)	0	1	0
Inside Callipers (3½ in.)	0	1	0
Spring Dividers or Wing Compasses	0	2	0
Centre Punch	0	0	6
File, Flat (Second Cut, 10 in.), with handle	0	1	0
File, Half Round, 10 in., with handle	0	0	11
File, Half Round, 6 in., with handle	0	0	7
File, Round, 8 in., with handle	0	0	9
File, Square, 8 in., with handle	0	0	9
File, Triangular, 6 in., with handle	0	0	7
Standard Vice with drawer	3	0	0
Drawing Board T-Square Set Squares 45° and 60° Scale Compasses	0	3	0

TOOLS AND MACHINES FOR GENERAL USE

Six Cast Iron Surface Plates (18 in. × 10 in. × ¾ in., planed only).	3	15	0
One Cast Iron Surface Plate (12 in. × 10 in., scraped, with ribs and handles)	4	0	0
Twelve Scribing Blocks	2	14	0
One set of Taps and Wrenches, ⅛ in. to ½ in. One set of Stocks and Dies, ⅛ in. to ½ in.	3	0	0
Two Soldering Bits	0	2	6

	£	s.	d.
One Gas Stove for heating Bits	0	4	6
Two pairs Tinman's Snips	0	5	0
Two pairs Pliers, Round and Flat-Nosed	0	3	0
One Hacksaw and Six Blades	0	5	0
Two Wrought Iron Blocks, for cutting-out purposes	0	7	0
Four pairs Spring Dividers, 7 in.	0	10	0
Six dozen additional Files (assorted)	2	10	0
One Shearing Machine (lever)	2	2	0
One Screw Press (complete)	5	0	0
One Bench Drilling Machine, with set of Drills	4	10	0
One Grindstone	3	0	0
One Brazier and Forge (complete)	6	0	0
One Anvil	2	0	0
One Cast Iron Water Trough	1	0	0
One Smith's Hand Hammer	0	2	6
One Sledge Hammer	0	6	0
Tongs, Hollow Bit	0	2	6
Tongs, Pincer	0	2	6
Tongs, Flat	0	2	6
Swages, Top and Bottom	0	4	10
Fullers, Top and Bottom	0	4	10
Flatter or Set Hammer	0	2	3
Anvil Cutter or Hardie	0	1	6
Hot Set	0	2	6
Cold Set	0	2	6
Round Punch	0	1	0
Square Punch	0	1	0
Poker, Rake, Slice	0	2	0
Swage Block and Stand	1	7	6
Two Lathes (complete)	29	0	0

The average cost of Tools and Machinery for a Manual Training Centre without power is about £150.

For a Centre, with Motor and Shafting, and a better class of Machinery, the average cost would be about £250.

The above tools, which are well adapted for use in a Manual Training Centre, are taken from the Catalogue of Messrs Syer & Co., 45 Wilson Street, London.

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